



**N A S A Space Environment
Test Chamber and Solar
Radiation Simulator**

OTS
Xerox Price _____
Microfilm Price _____

**THE UNIVERSITY OF ROCHESTER
COLLEGE OF ENGINEERING
ROCHESTER, NEW YORK**

25

FINAL REPORT

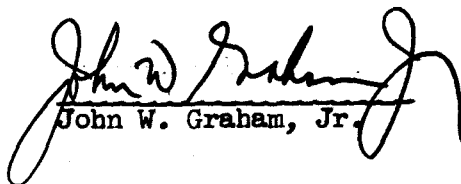
NASA SPACE ENVIRONMENT TEST CHAMBER
AND SOLAR RADIATION SIMULATOR

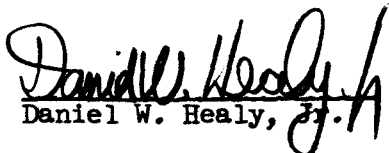
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Contract No. NAS w-181

Approved

Date

October 20, 1961


John W. Graham, Jr.


Daniel W. Healy, Jr.

FINAL REPORTNASA SPACE CHAMBER AND SOLAR SIMULATOR PROJECT

I. Objective

The initial phases of the work undertaken under this contract, namely, to study the problem associated with building a space chamber complete with light source capable of simulating the sun's spectrum in outer space, were reported in a report dated November 1960, entitled "Preliminary Report - NASA Space Environment Test Chamber and Solar Radiation Simulator". Work described therein will not be repeated here. Some additional copies of that report will be distributed along with this for the sake of completeness. Other copies may be secured by writing the College of Engineering, University of Rochester, Rochester 20, N. Y.

This report will be concerned with the work undertaken to gather data on lamps which might be suitable sources of light for use in a solar simulator. In considering the problem of constructing a suitable environmental test chamber, it rapidly became evident that the central problem was one of finding reliable data about possible light sources. For the most part, the high intensity lamps available commercially were constructed with purposes such as outdoor movie projectors in mind. Here, visual color fidelity over short fixed intervals of operation were important, and very little data on wideband spectral characteristics, spectral stability, life, efficiency, and reliability were available.

At the time we were preparing to collect data on potentially useful light sources, it was brought to our attention that the Bausch and Lomb Co., also of Rochester, New York, was embarking on a program to build solar simulators and were also interested in a study of suitable light sources. As a

result of this mutual interest and because our combined facilities proved superior to those either of us could provide alone, we entered upon an agreement to pool our interests in this manner and to develop a laboratory facility at the College of Engineering, University of Rochester, to evaluate possible lamps.

The data reported here is a result of this cooperative agreement, results derived from lamps tested in our laboratories, results of tests made at Bausch and Lomb laboratories, and, in a few cases, tests made at the site of the lamp manufacturers.

Initially, it was decided to test a group of 2.5 kilowatt short-arc D.C. design mercury xenon lamps. These lamps were made (on special order of Bausch and Lomb) by Hanovia Lamp Co. of Newark, New Jersey, and Westinghouse Corporation of Bloomfield, New Jersey. The use of enclosed lamps rather than carbon arcs had by this time seemed desirable because of the very discouraging experiences of people who had tried to operate a small number of high-power carbon arcs for a reasonably long period of time. Certainly, while the carbon arc much more nearly matches the solar spectrum than any other single light source, it seemed clear that operating difficulties more than overcame this advantage.

II. Test Laboratory

A test laboratory was set up in a room of about 600 sq. feet of floor area. Ten explosion-proof and nearly light-tight boxes were constructed and arranged in this room. Each box was equipped with a blower and air-cooling duct individually led to the outside air. This proved necessary to keep the

temperature down to a tolerable level in the room as well as to get rid of the ozone produced. A single unshielded 2.5 kw lamp creates an objectionable and perhaps dangerous level of ozone in an enclosed room.

A primary source of electrical power capable of providing 60 volts d.c. at 800 amperes was wired into the laboratory. Each lamp box was fed from this source through appropriate ballast resistors. The primary supply voltage and current through each lamp were separately monitored and continuously recorded. Elapsed time hour-meters kept track of the running time for each lamp.

In operation, the lamps, after about 15 minutes of warm-up time, settled down to very stable current requirements. Individual lamps, however, differed among themselves by as much as 10 amperes at a fixed voltage. Each lamp was operated at as close to 2500 watts as was practical by adjustments of the ballast resistors.

III. Tests on Lamp Intensity Versus Life

Ten lamps were tested in this program, five supplied by Hanovia and five supplied by Westinghouse. Figures 1 and 2 are sketches of these lamps. The following data applies to all the lamps for normal operating conditions and life:

Operating volts $50v \pm 5v$

Operating current $50a \pm 5a$

Operating power (rated) 2.5 KW

Arc gap spacing 4 - 4.5 mm (Hot)

Voltage immediately after start 15v

Starting voltage D.C. 60v minimum (Lamp Cold)

All lamps started using an Osram

High voltage starter model Z 5203

Anode operated up

Conical shaped anode - See Figures 1 and 2

Cooling air of approximately 30 CFM passed from
top to bottom over the lamp.

The purpose of these tests was to determine the decrease in intensity of the lamps during their lifetime. The lamps were operated continuously 24 hours a day until their intensity decreased by at least 25 per cent.

An Eppley 50 Junction Pyroheliometer was used to measure the intensity of the light at regular intervals. The pyroheliometer was mounted in the same horizontal plane as the lamp arc at a distance of 23.25 inches as shown in Figure 3. The pyroheliometer was positioned carefully in the center of the beam of light leaving the slit, exposing the whole pyroheliometer bulb to radiation.

The output of the pyroheliometer was measured by a Leeds and Northrup No. 8662 Portable Precision Potentiometer.

Changes of ambient illumination level of the room from day to day were corrected for by monitoring the pyroheliometer for ambient illumination and subtracting this from the measured output of the lamps. In addition, a correction was made for the fact that the lamps were not held at exactly rated power. A measurement of input power was made each time the lamp light intensity was measured and a linear correction factor applied. It had been determined experimentally that lamp intensity was a linear function of input

electrical power over the ranges of power fluctuation observed.

Normal intensity measurements varied from 4 to 8 millivolts. The conversion factor for the pyroheliometer is $9.85 \text{ millivolts/gm cal/cm}^2/\text{min} = 65 \text{ watts/sq. ft.}$, therefore, the intensity measured varied from 26 to 53 watts/sq. ft.

The average lamp life measured as the time for light intensity to reach 80 percent of original intensity was 225 hours. These data are shown in Figure 4. There was considerable fluctuation in life for individual lamps; one lamp operated 800 hours and still produced 82% of the original light intensity, while another dropped to the 80% level in 100 hours of operation. Individual lamp performances are shown in Figures 5 through 14.

The relatively short life of the lamps was felt to be due to two factors, primarily

(a) the darkening of the lamp envelope due to evaporation deposition of anode material. Some lamp envelopes became nearly opaque after test.

(b) the increased arc spacing and concomitant reduced brightness as the anode material eroded away.

Both of these factors are the result of excessive anode temperatures. This effect can be materially improved by redesign of the anode configuration. We believe a spherical or flattened shape will produce longer life by permitting greater heat dissipation as well as providing more anode material.

As indicated in the data, tests on some lamps were terminated by explosion of the lamps. In all cases, these were quite violent and only

very small quartz fragments of the lamp envelope remained. In two cases, these explosions occurred immediately after the lamp had been restarted after a short shut down. In the other cases, the explosions were not observed. It seems quite probable that these explosions resulted from heat stresses in the envelope, and in operating a large number of lamps care would have to be maintained to prevent sudden heat changes.

Figure 15 shows measurements taken by the Westinghouse Corporation showing intensity of light output versus power input over a wide range of power input.

IV. Light Intensity Pattern

From the lamp configuration it seems reasonably safe to conclude that the azimuthal distribution of light intensity is circularly symmetric. However, this is not true for the vertical plane and measurements of the light intensity versus polar angle were made on seven of the 2.5 kw mercury-xenon lamps. These tests were made at the site of the Hanovia Company, as they had an installation set up for this work. The lamp to be tested was placed with the center of the arc accurately positioned in the center of blackened integrating sphere. After the lamp had reached stable operating conditions, a photo detector was moved in 5-degree increments along a slit in the sphere. The results are shown plotted in Figures 16-21. The light intensity measurements are relative values only, because the photodetector, although linear in this range, was uncalibrated.

V. Light Spectral Characteristics

Figure 22 shows the typical setup for taking data on the spectral characteristics of the test lamps. The data was taken with a Perkin-Elmer Model 83 Monochromator equipped with quartz prisms and using a vacuum thermocouple as a detector. The thermocouple signals were amplified by a Perkin-Elmer Model 13 a.c. amplifier and registered on a Speedomax chart recorder.

An image of the hot spot of the test lamps was focused through one parabolic and one flat aluminized mirror on the entrance slit of the monochromator. The slit width was set at an indicated 0.1 mm. and scans were made of the spectral distribution of the energy in the wavelength region from 0.25 to 2.5 microns.

When a lamp was first placed on test, a slow-speed (approx. 30 min.) scan of its spectral characteristics was made. Thereafter, spectral characteristics were made at intervals of about 100 hours of lamp operation. These tests were made at higher speeds (about 6 min/scan). Finally, when the lamp appeared near the end of its useful life, another slow-speed scan was made. The data so recorded were plotted from the Speedomax chart corrected for relative intensity variation of the system and plotted as shown in Figures 23 to 33.

The system was calibrated using the same optics against two overlapping range ribbon filament National Bureau of Standards standard lamps, a Tungsten filament lamp supplied by N.B.S. March 8, 1961 designated E-59 and calibrated from 0.5 to 2.6 μ , and a Tungsten filament lamp supplied by

N.B.S. February 27, 1961 designated V-44 and calibrated from 0.25 to 0.75 μ . In making the calibration runs, the slit width of the monochromator was increased to an indicated 1.0 mm.

The following conclusions may be reached from these tests:

- (a) The spectrum is very uniform from lamp to lamp.
- (b) Both the Hanovia and Westinghouse lamps have a similar spectrum.
- (c) There were no spectral shifts in the position of the lines with lamp aging.
- (d) The spectral energy distribution changed with age according to the following averaged data:

<u>Hours</u>	<u>UV 300-400 μ</u>	<u>Visible 400-700 μ</u>	<u>IR 700-2000 μ</u>
1	19%	53%	28%
133	10%	46%	44%
447	8%	40%	52%
712	7%	36%	57%

VI. In addition to studying the characteristics of commercially available light sources we were also interested in finding new possibilities. One of these possibilities was to use a plasma jet to simulate solar radiation. It was thought that a reasonably close match of the solar spectrum might be attained by using a judiciously chosen mixture of gases in the jet, and the output of continuum radiation might be increased by introducing solid materials

like tungsten into the jet in powder form.

A plasma torch which can handle the above mentioned requirements is manufactured by the "Thermal-Dynamics" Corporation of Lebanon, N. H. For our experiments we purchased an F-40 Plasma Torch with control equipment, a 12.5 kw power supply and a spraying attachment for the torch.

This equipment has been set up. After some initial difficulties everything is now operating satisfactorily. In the course of the initial experiments it became apparent, however, that the plasma jet should be enclosed in a well-ventilated box. Appreciable amounts of ozone are produced by the jet and if the jet is operated with nitrogen into air toxic nitrogen compounds are formed. This enclosure and the exhaust system have been built.

At the present time we are continuing our investigations. The spectrophotometer measurements are now centered at the intensity maximum of the jet radiation, and cover a range of about 1000° A on either side of this maximum. Measurements are being made for different jet currents. These measurements will give us an indication of the effective jet temperature and will provide information on the line spectrum which is most prominent in this region.

HANOVIA LAMP CO.
2.5 kw MERCURY XENON LAMP
CONICAL ANODE DESIGN

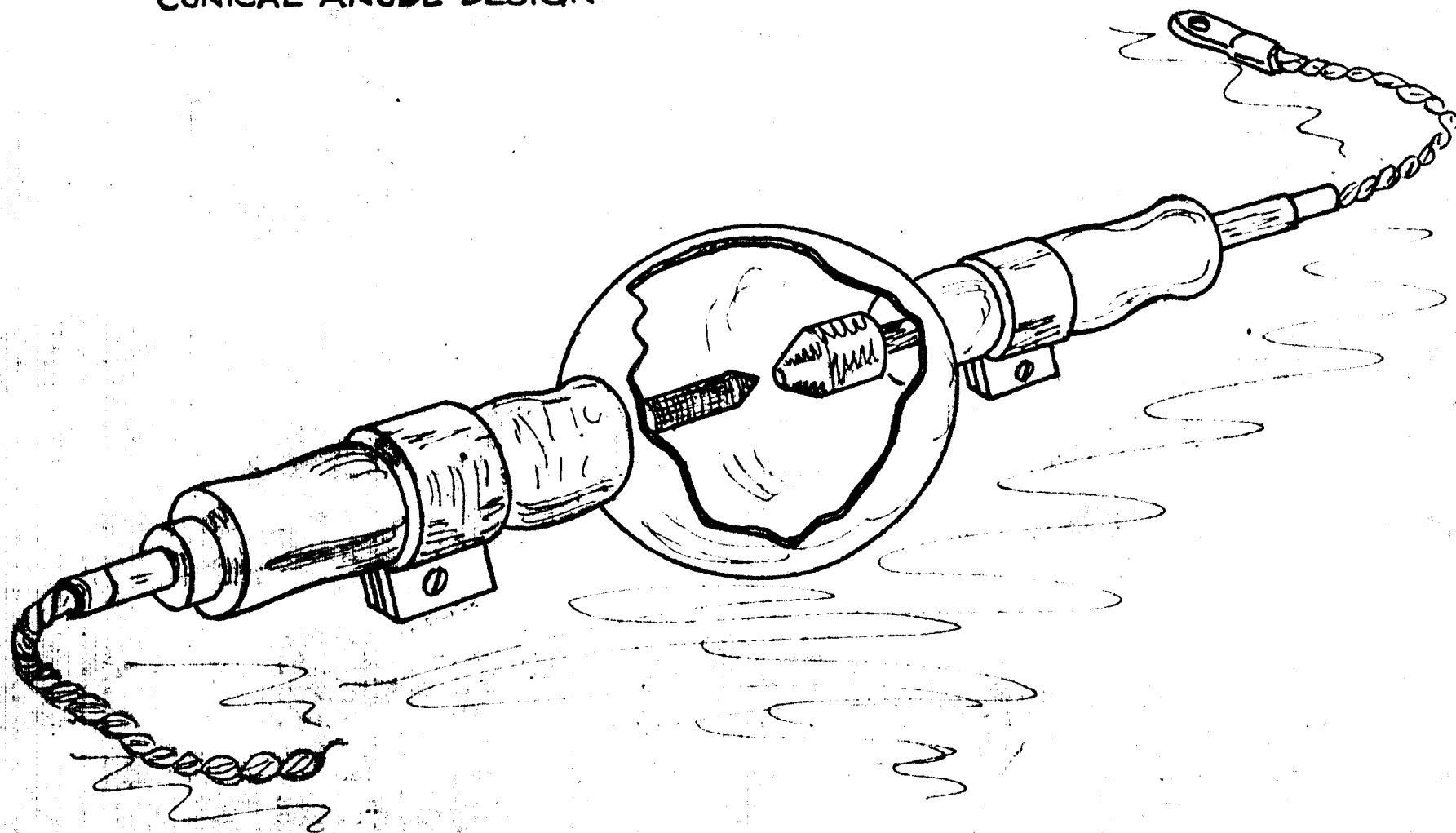
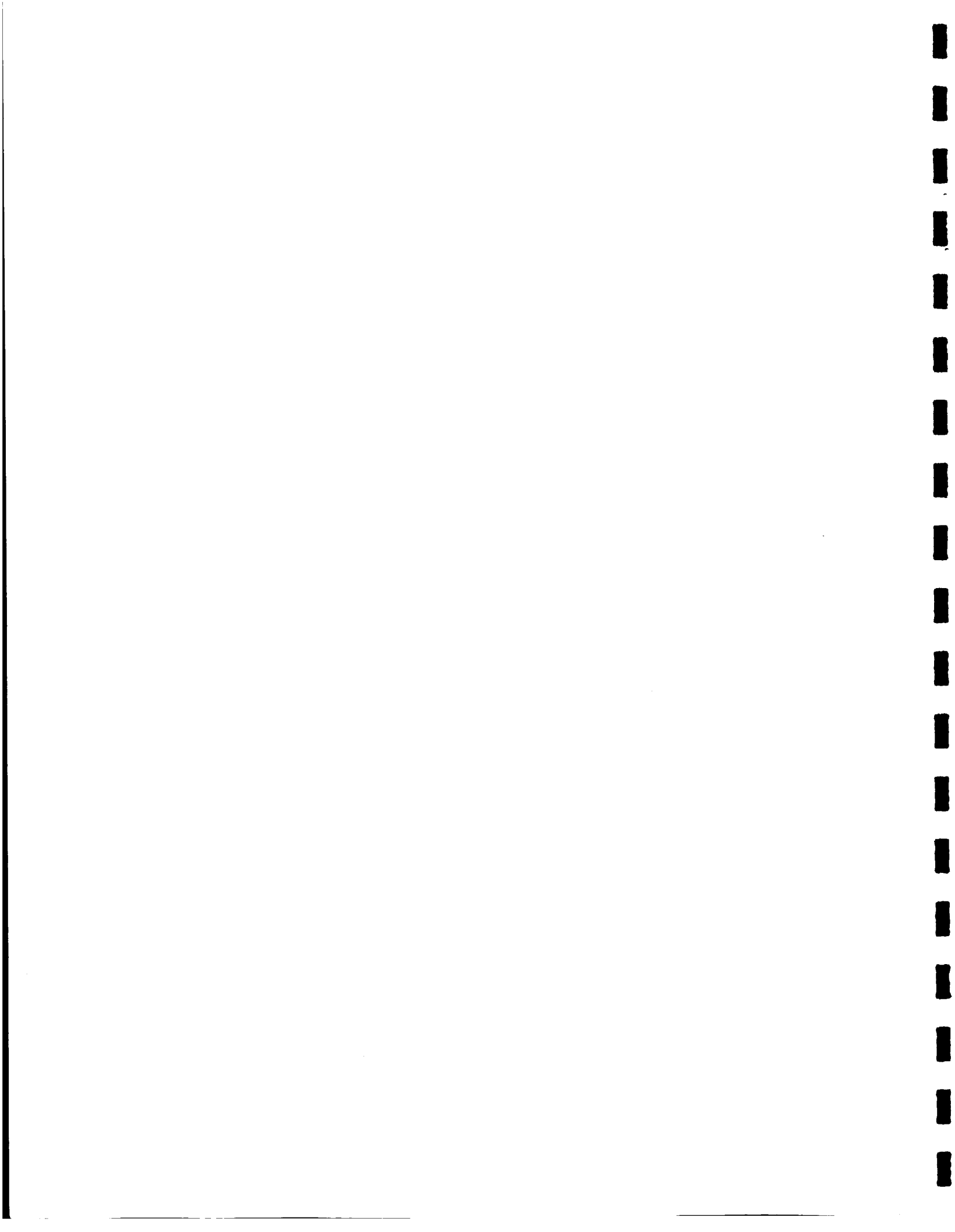


FIG. 1



WESTINGHOUSE ELECTRIC CORP.
2.5 kw MERCURY XENON LAMP
CONICAL ANODE DESIGN

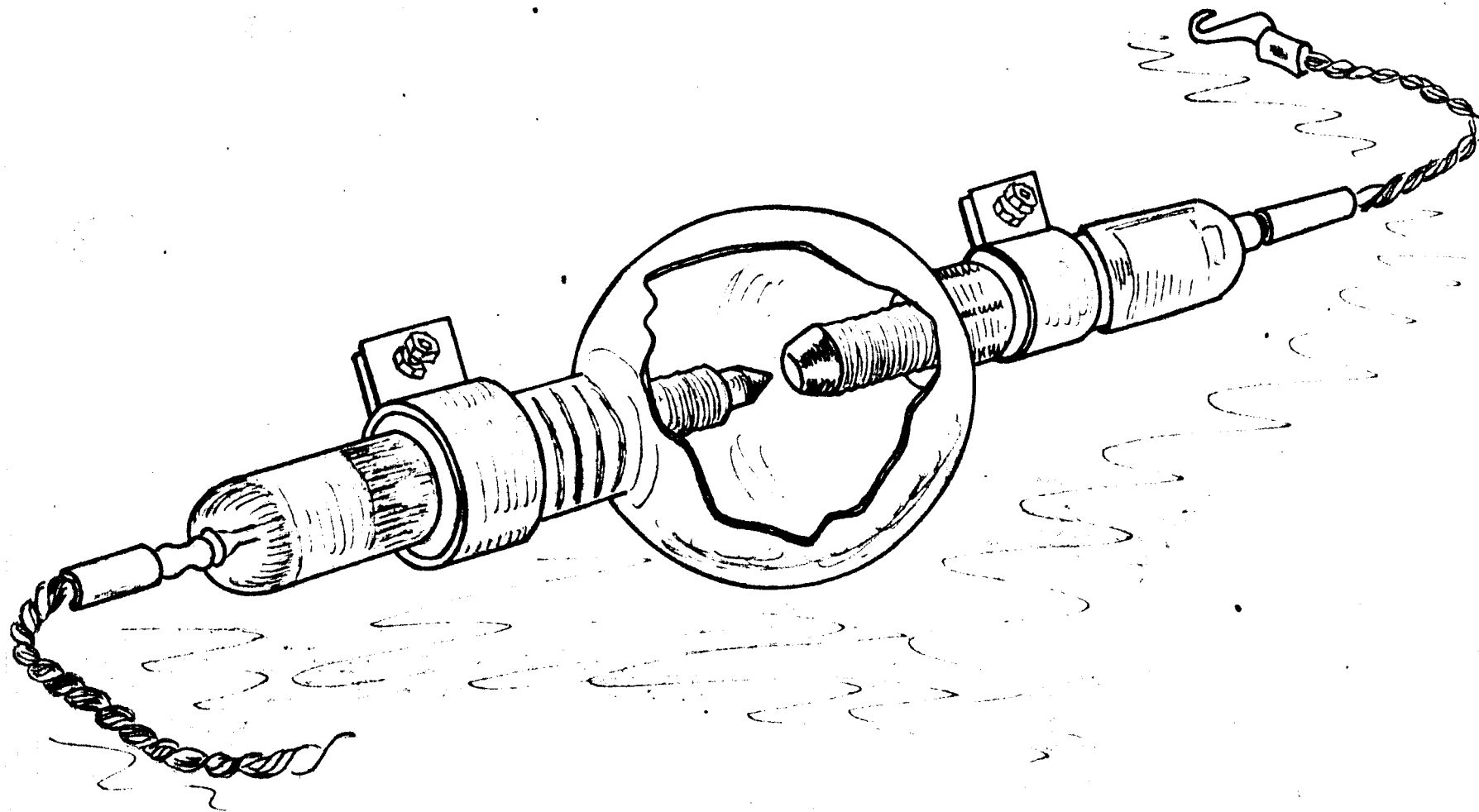


FIG. 2



INTENSITY MEASUREMENT

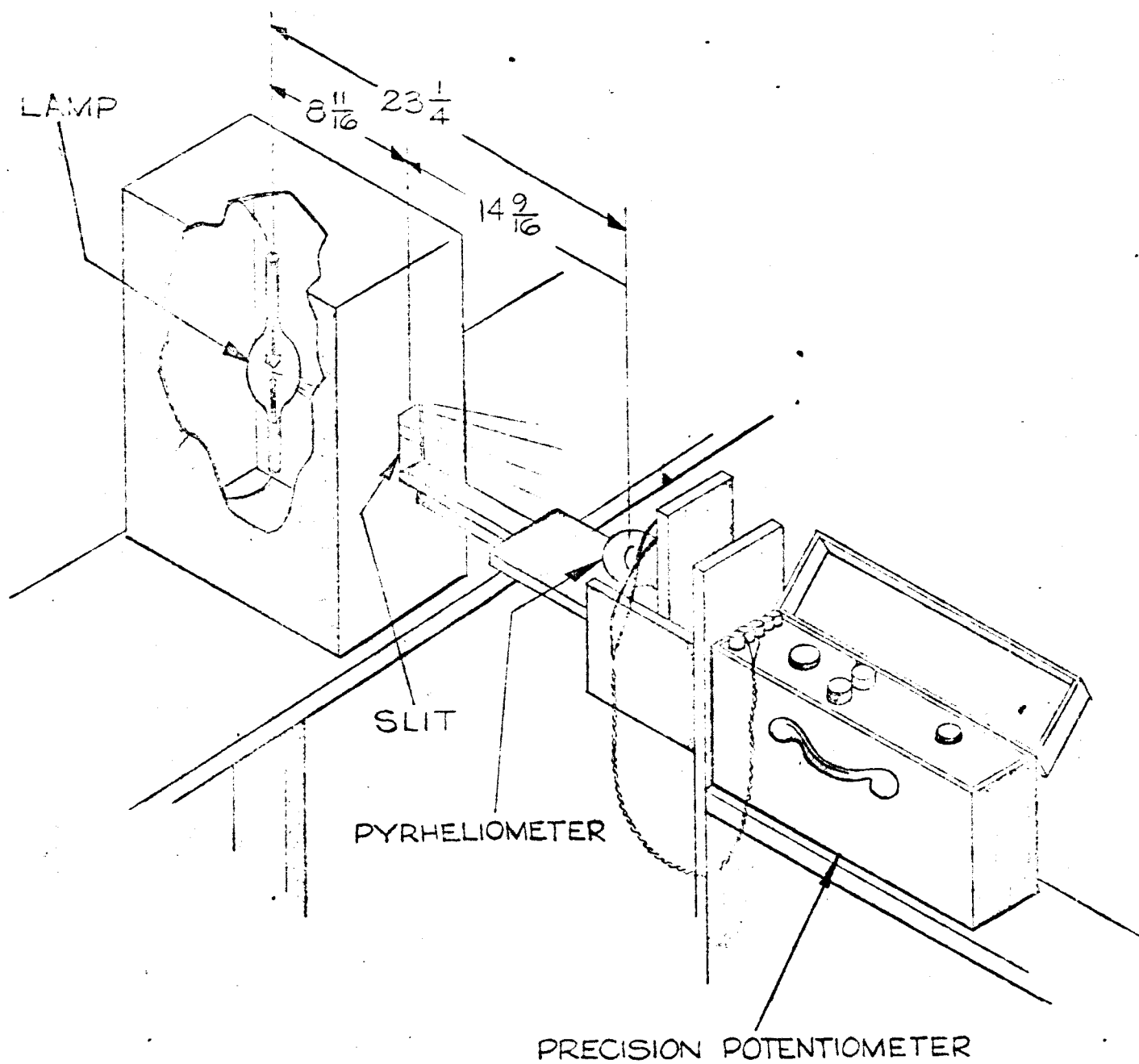
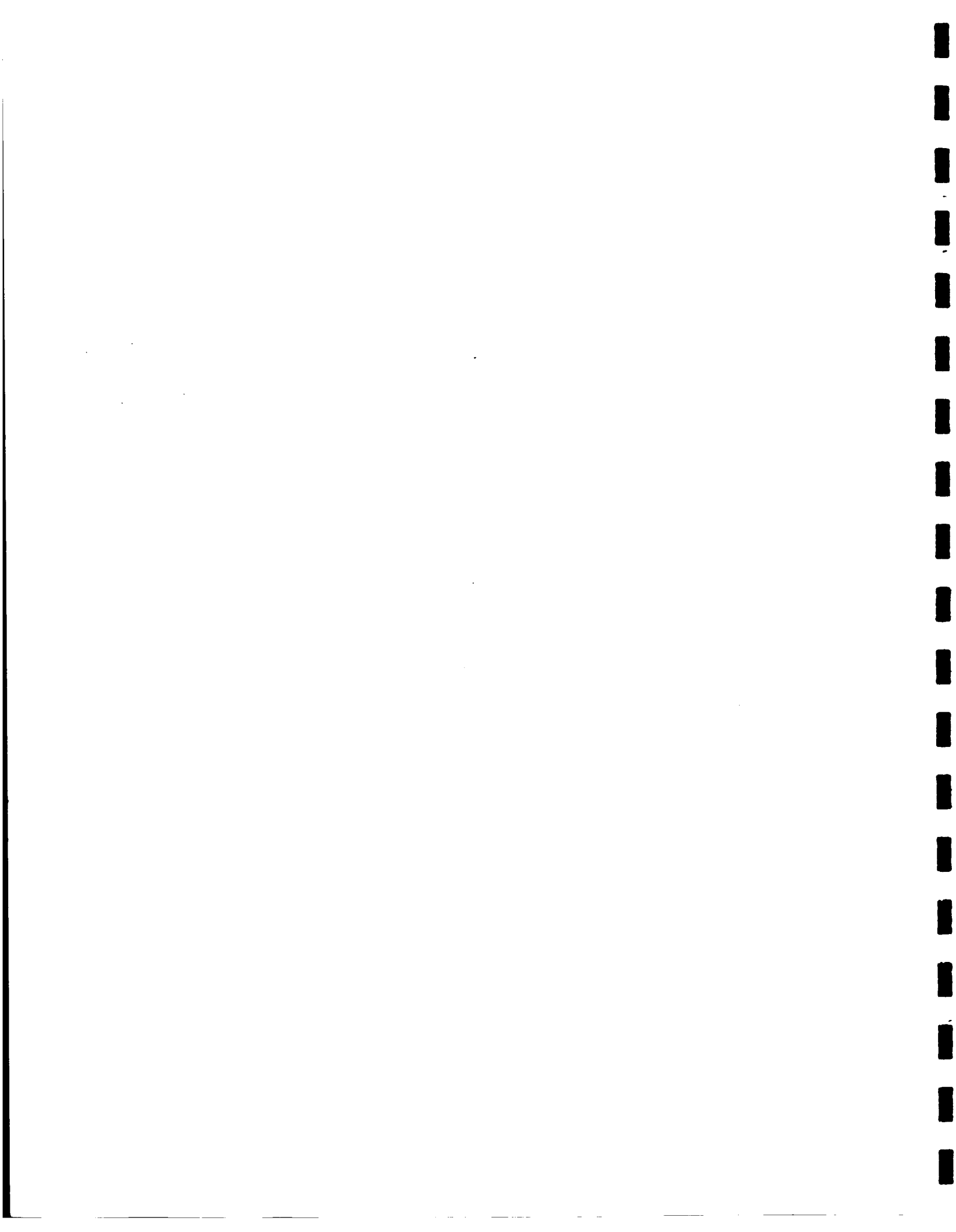


FIG.3



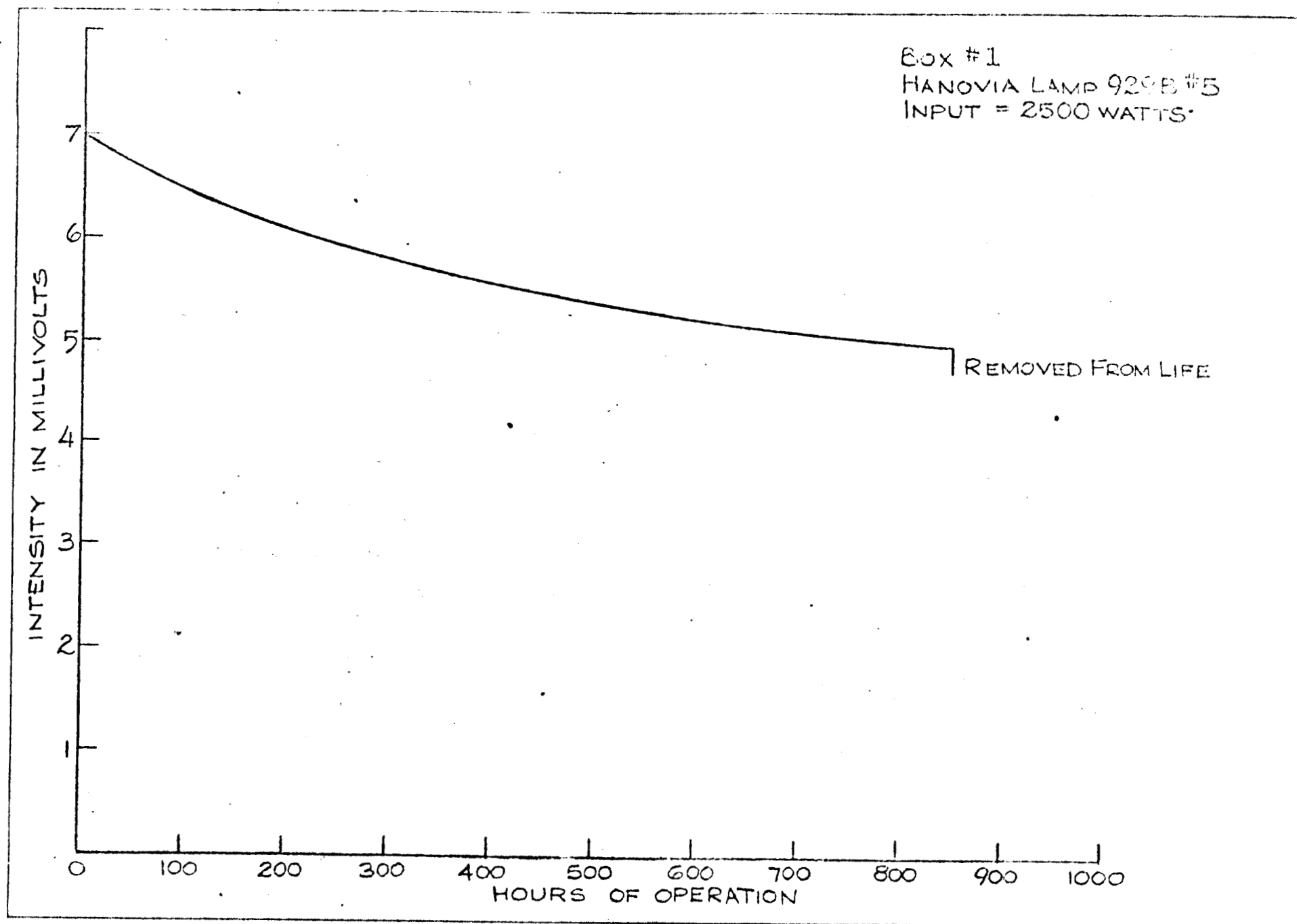


FIG. 5.

38

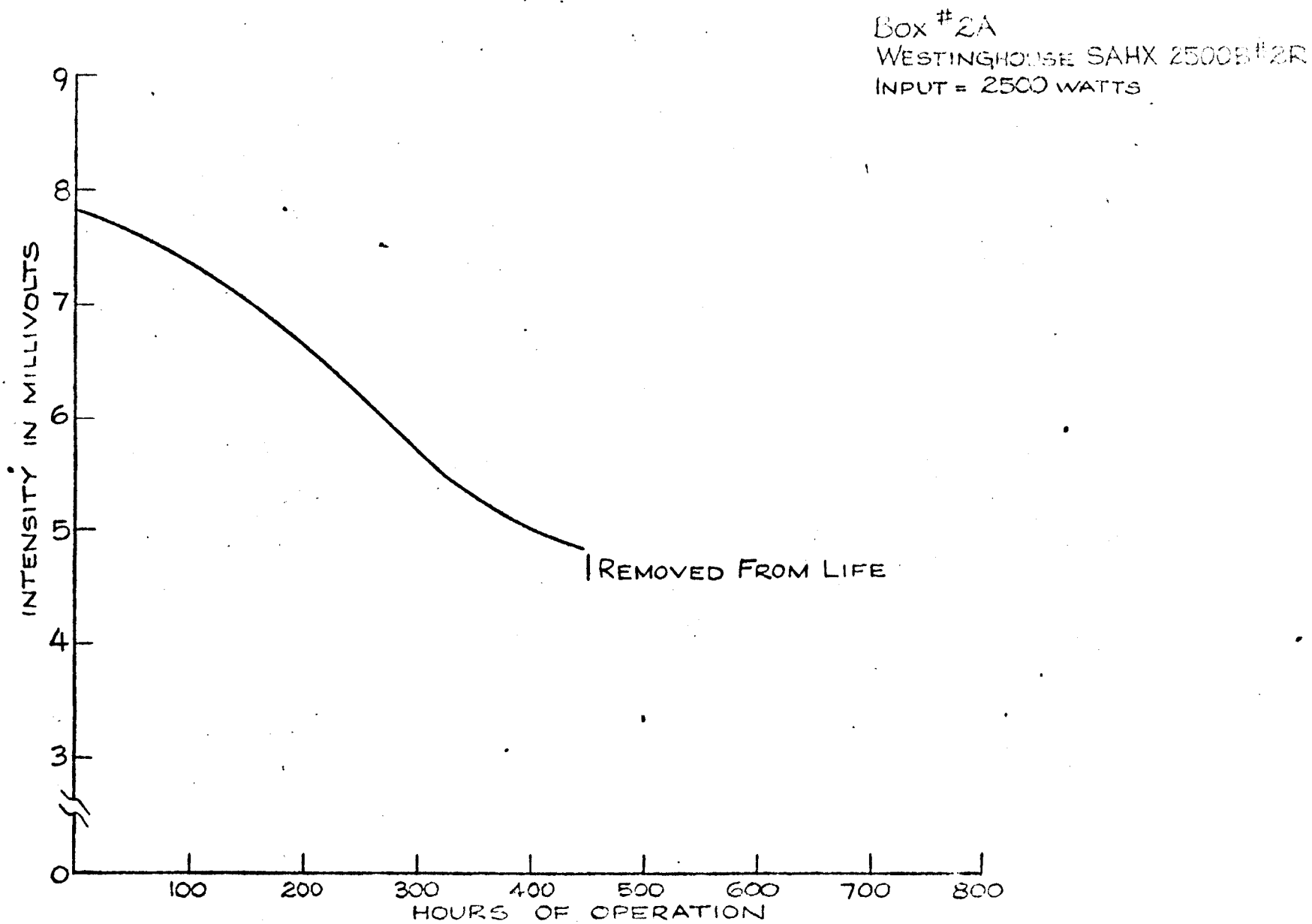
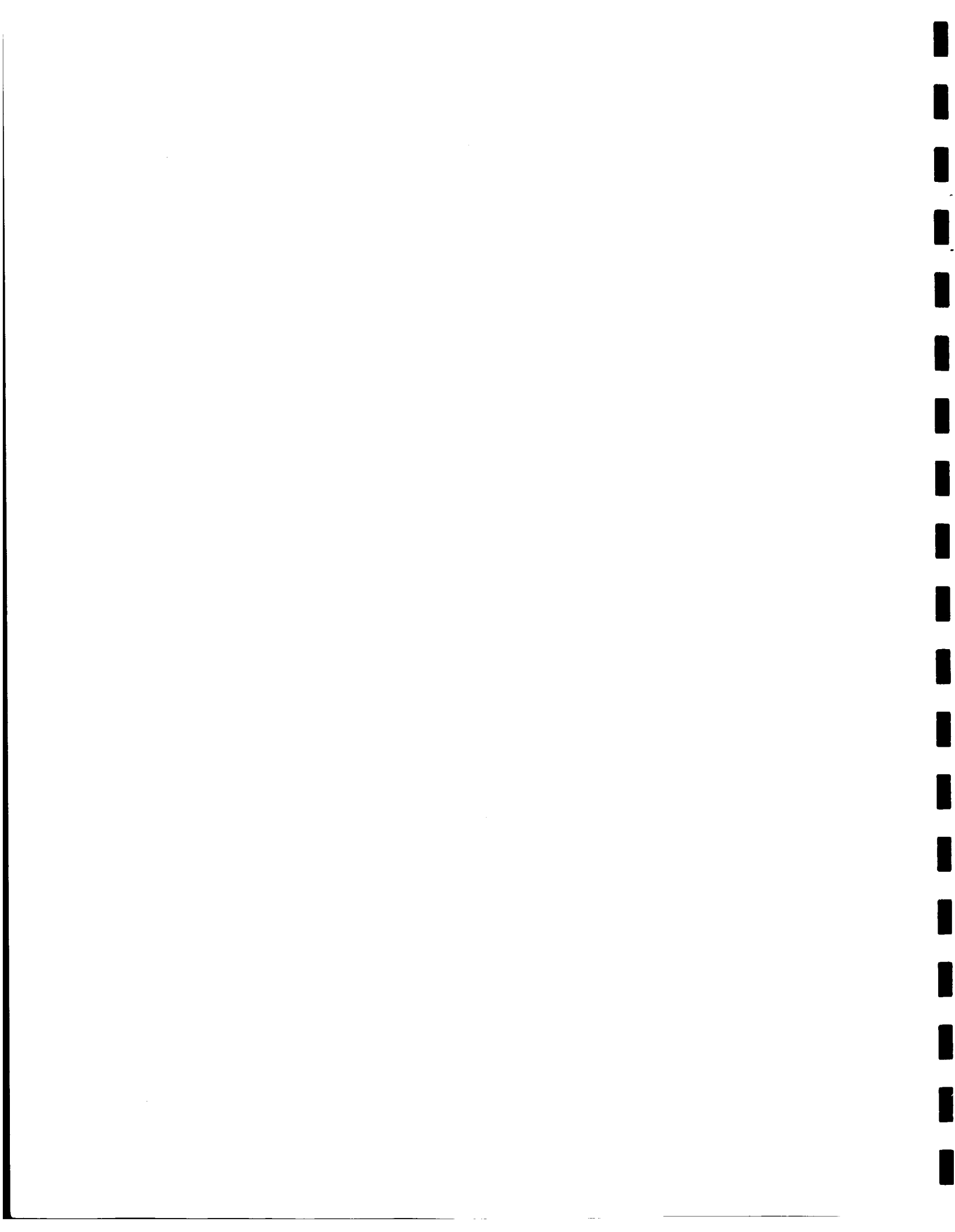


FIG. 6



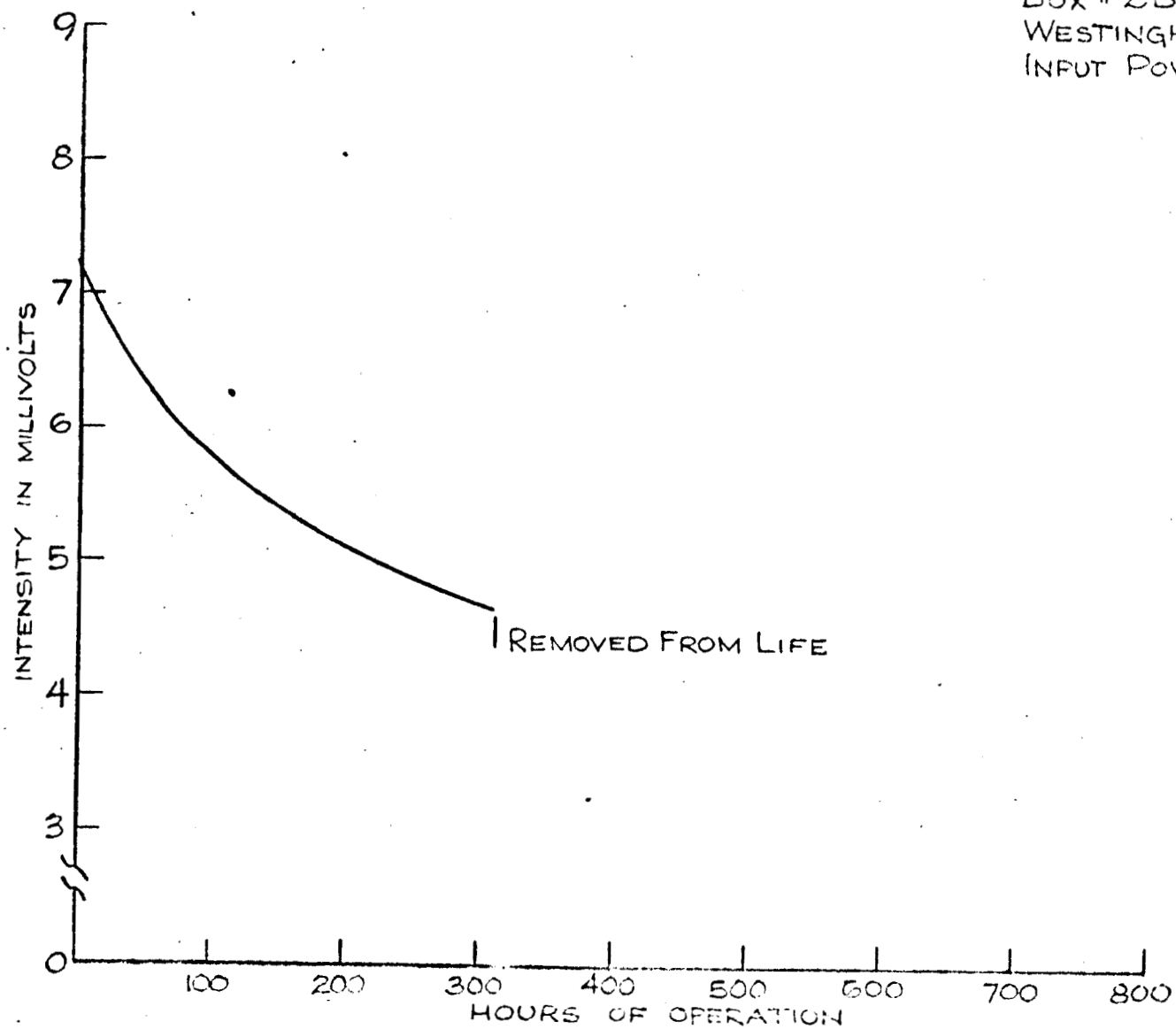
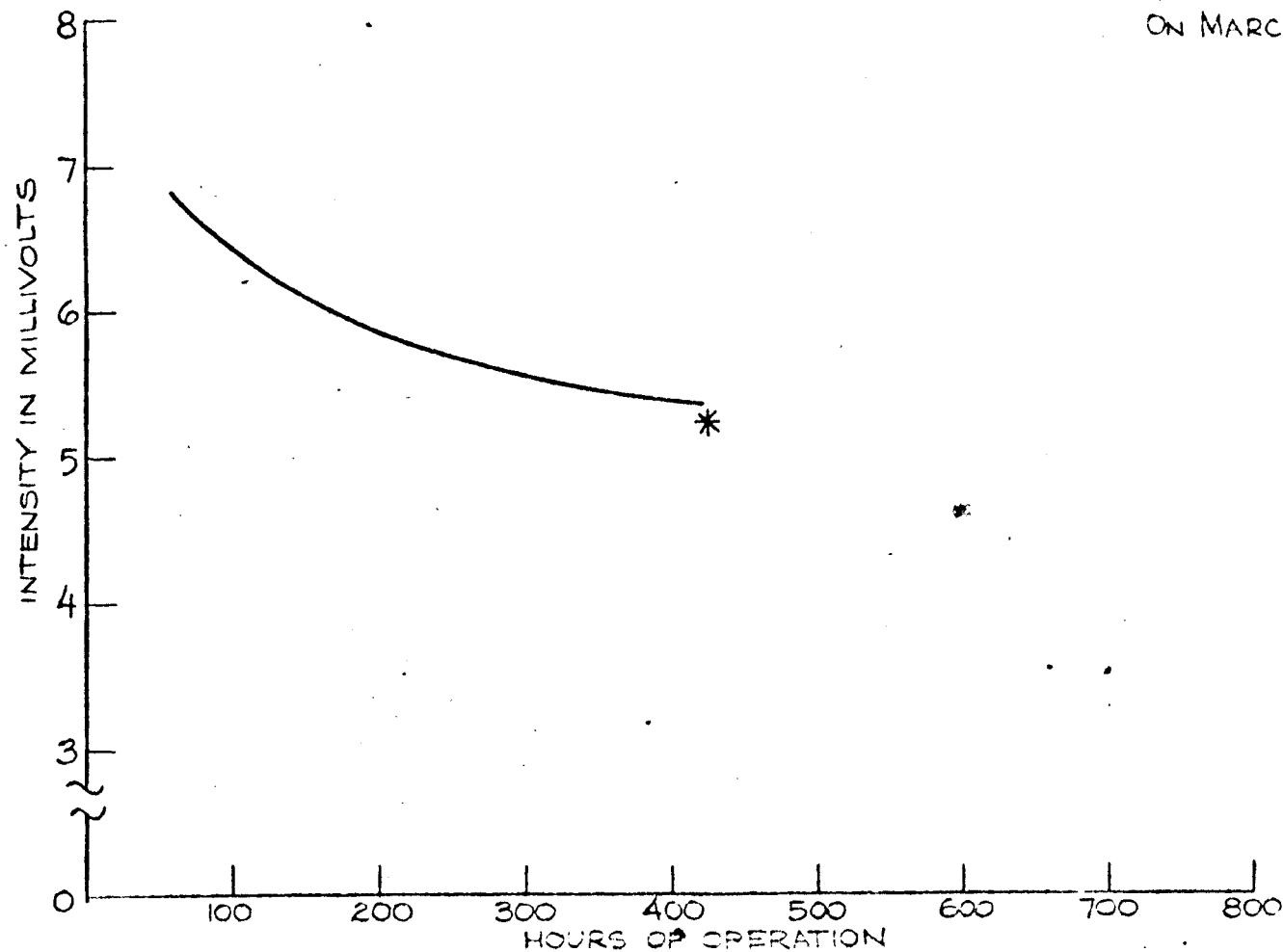


Fig. 7

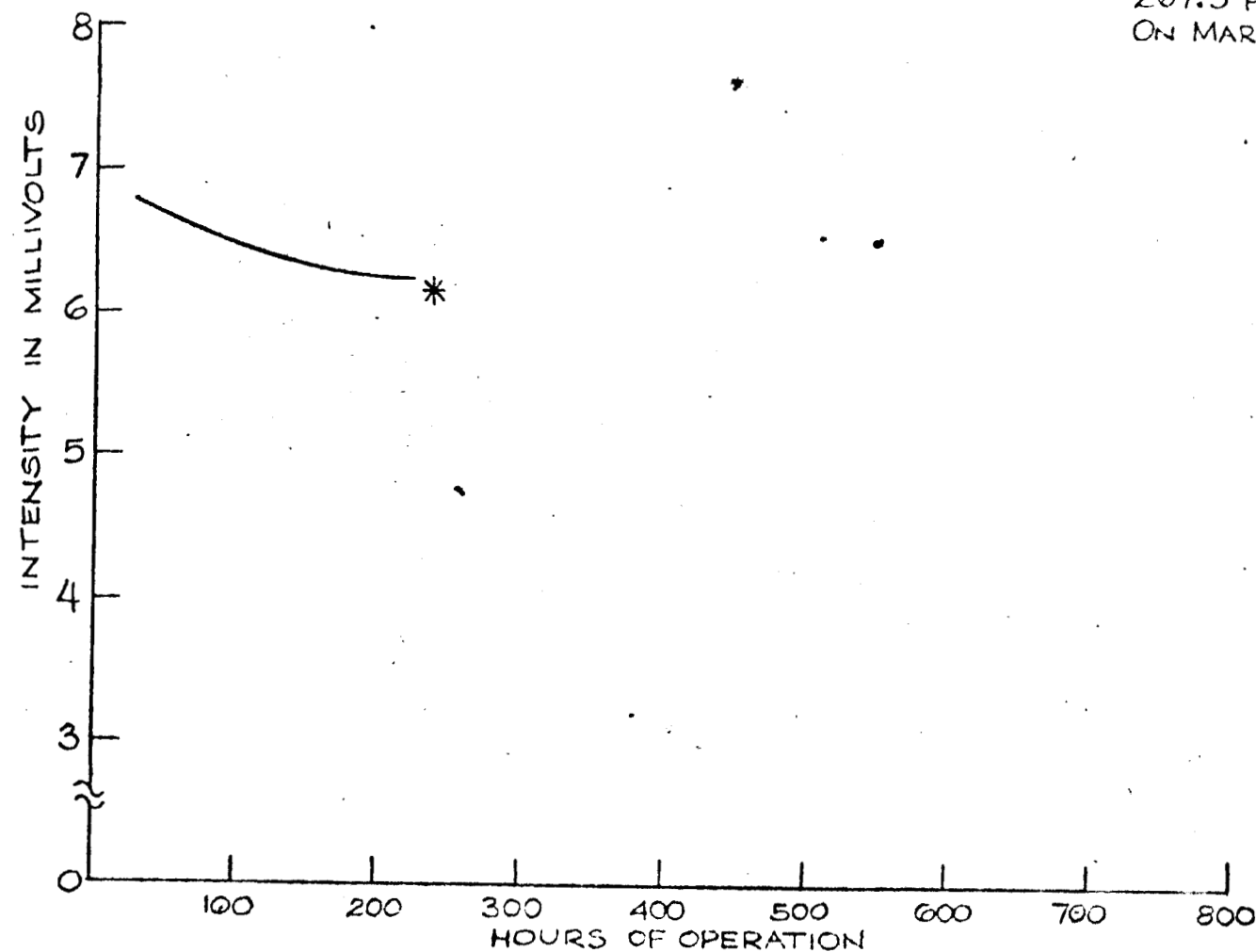


Box #3A
HANOVIA LAMP 929B #11
INPUT = 2500 WATTS

* THIS LAMP EXPLODED AFTER
424.7 HOURS OF OPERATION
ON MARCH 15, 1961

FIG. 8

5
3

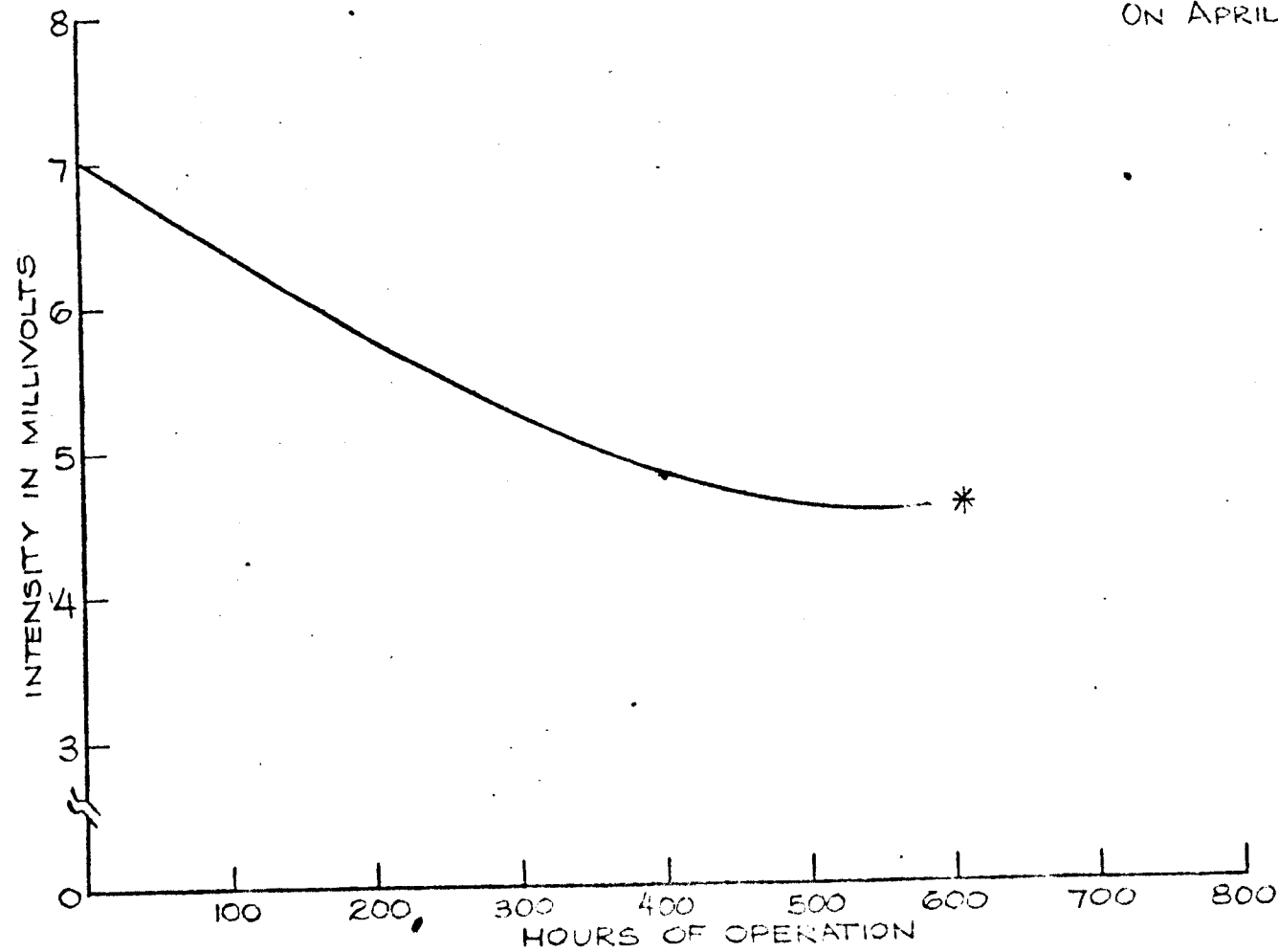


Box #4A
WESTINGHOUSE SAHX 2500 B-8R
INPUT = 2500 WATTS

* THIS LAMP EXPLODED AFTER
267.5 HOURS OF OPERATION
ON MARCH 10, 1961

FIG. 9

34



Box #1B
HANOVIA LAMP 929B #14
INPUT POWER = 2500 WATTS

* THIS LAMP EXPLODED AFTER
586 HOURS OF OPERATION
ON APRIL 8, 1961

Fig. 10

33

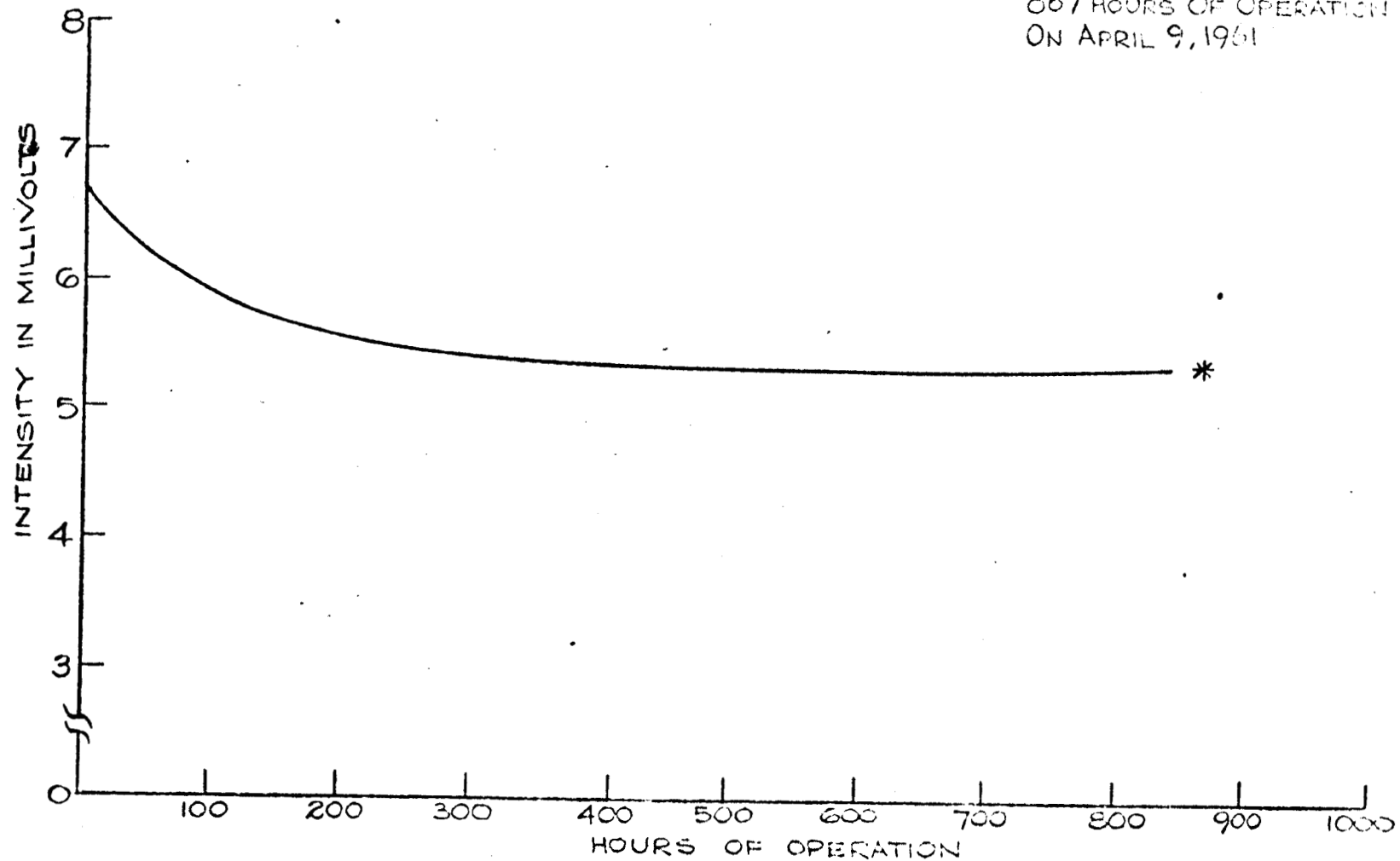


FIG. II.

32

Box #6
WESTINGHOUSE SAHX 2500B #4R
INPUT = 2500 WATTS

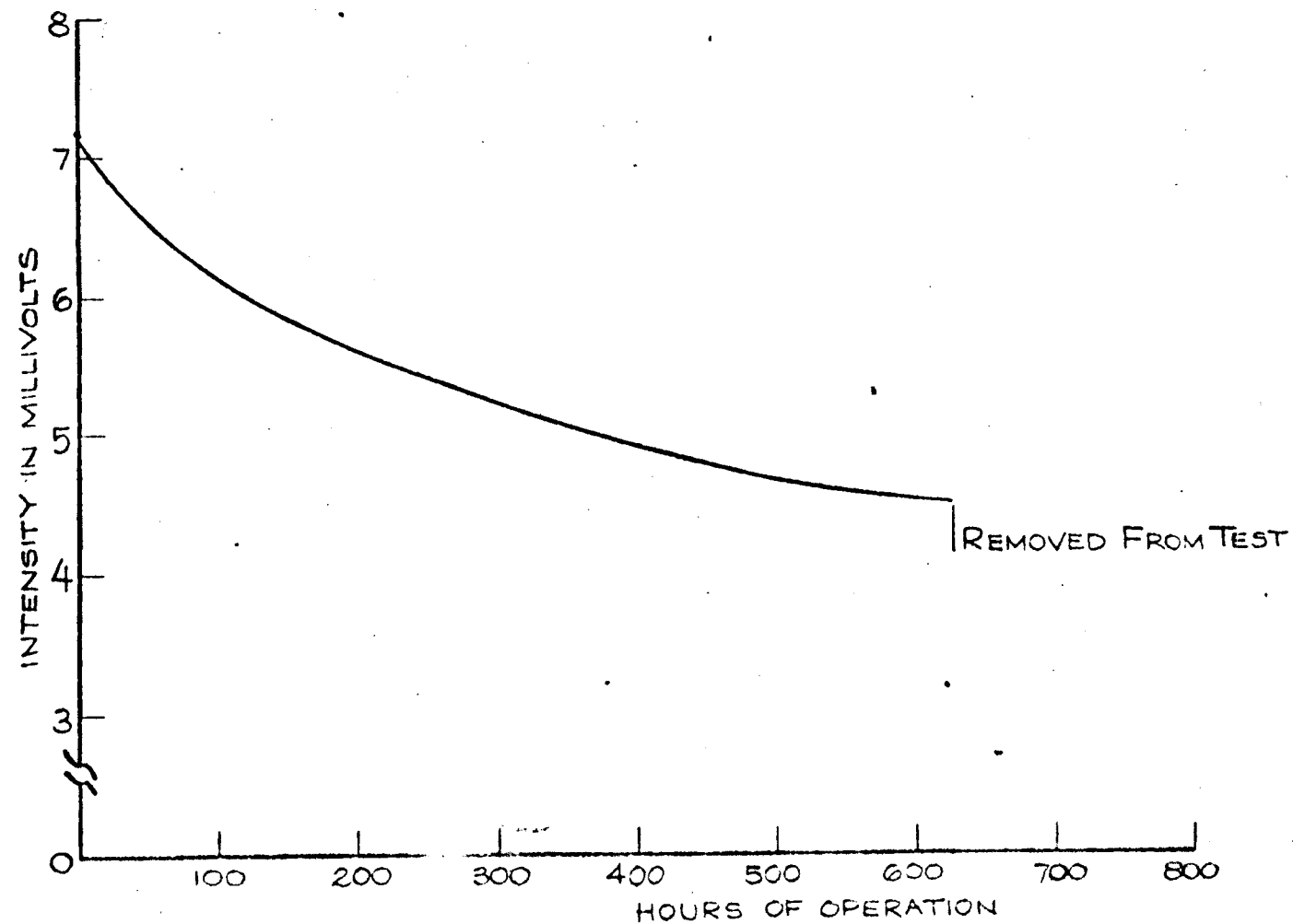


FIG. 12

Box #7
HANOVIA LAMP 9298 #4
INPUT POWER = 2500 WATTS

* THIS LAMP EXPLODED AFTER
550 HOURS OF OPERATION
ON MARCH 31, 1961

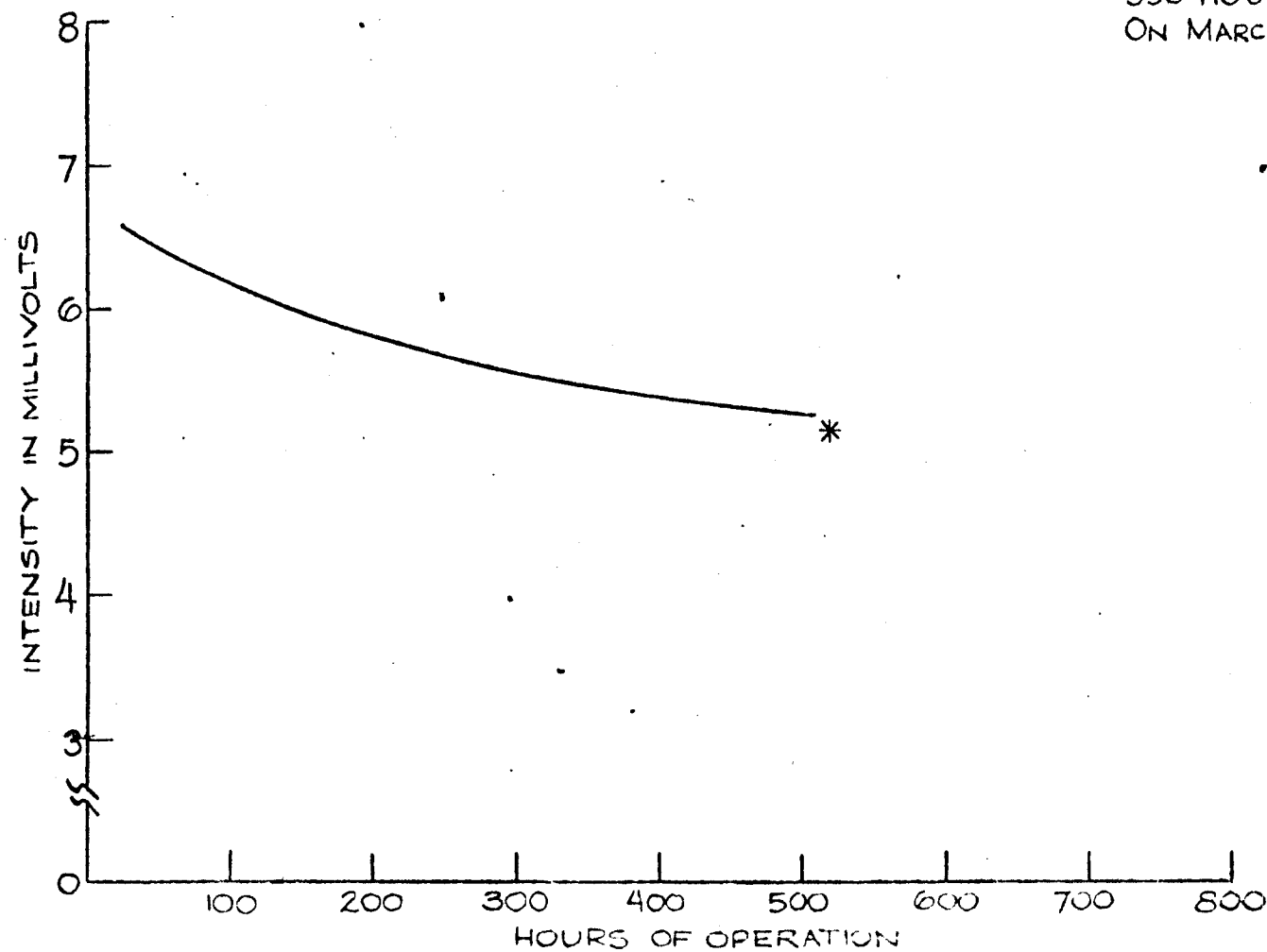


FIG. 13

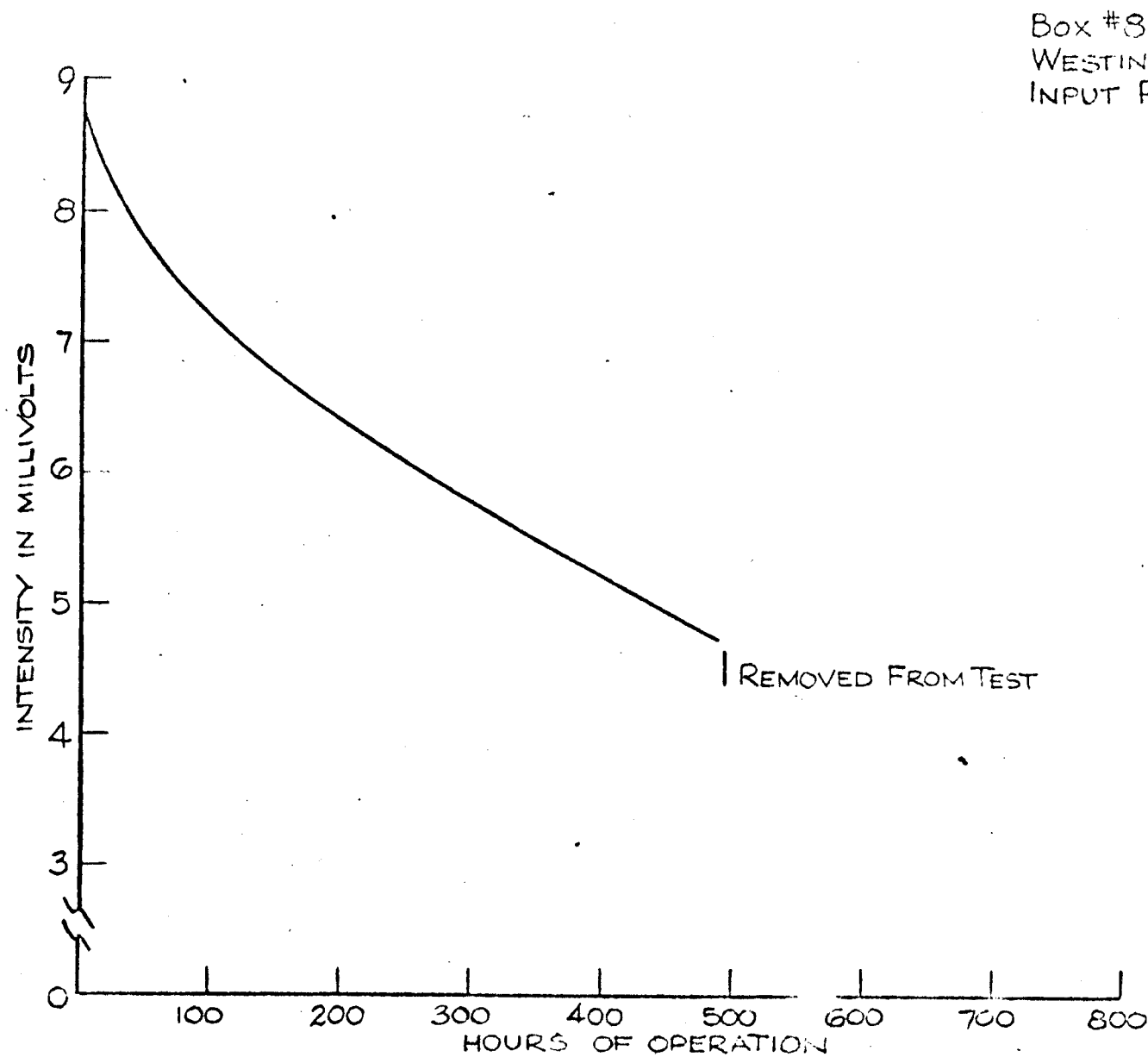


FIG. 14

29

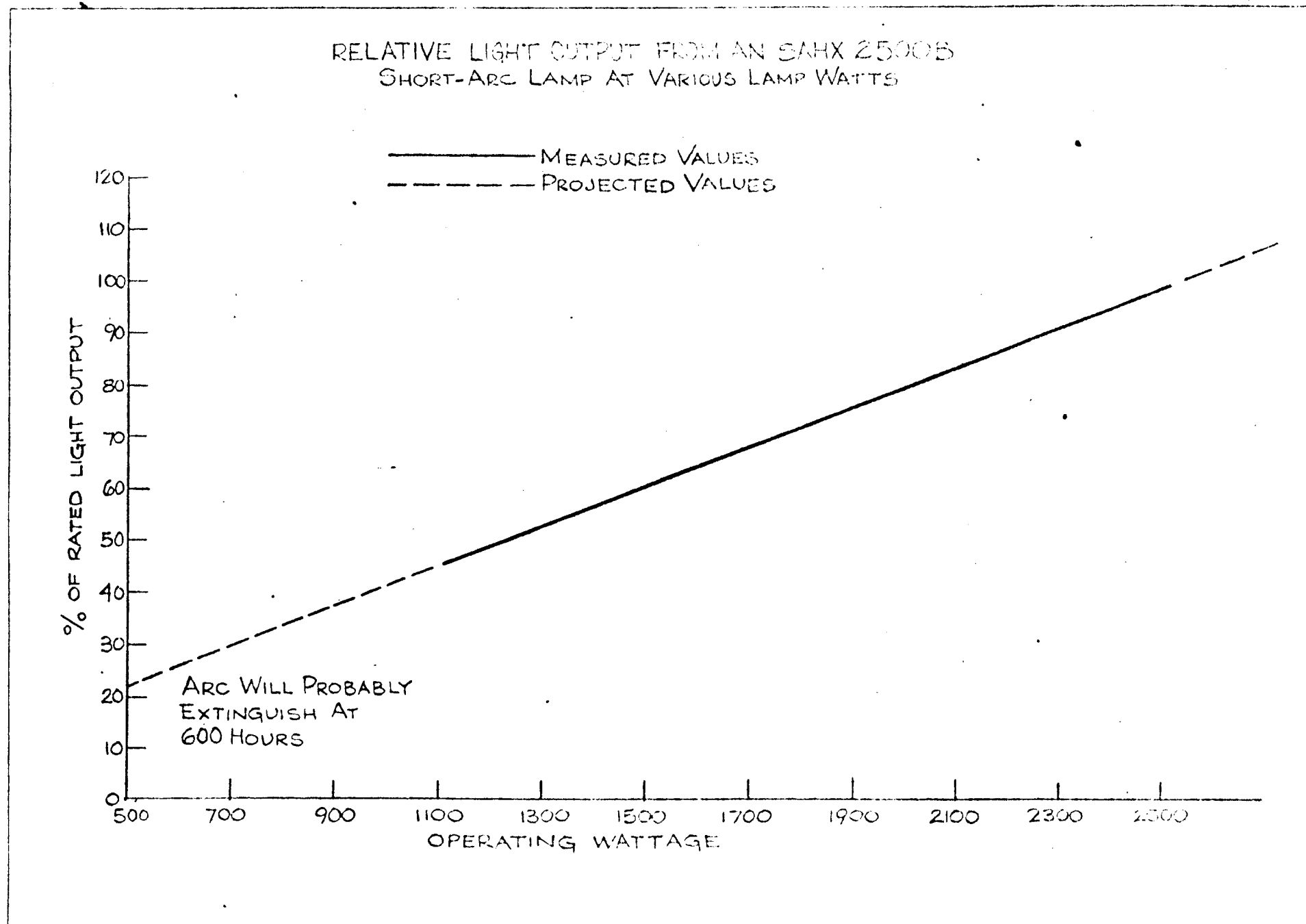


FIG. 15

RELATIVE
POLAR DISTRIBUTION
FOR 3 HANOVIA LAMPS
14 - NEW
4 - 147 HOURS OF LIFE
10 - 235 HOURS OF LIFE
OPERATED WITH ANODE UP

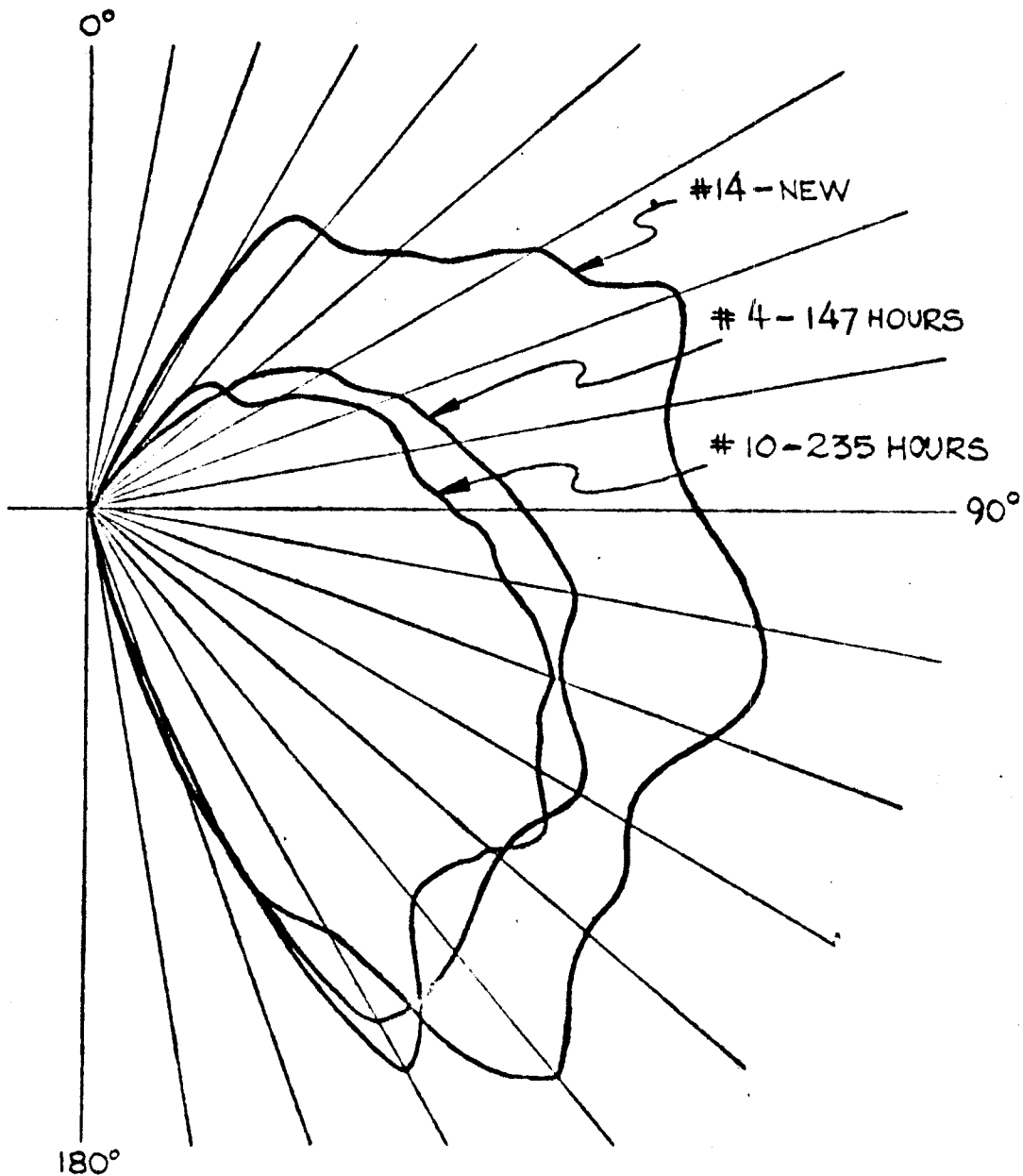


FIGURE 16

RELATIVE
POLAR DISTRIBUTION
FOR HANOVIA #17
WITH SPHERICAL ANODE
OPERATED AS SHOWN

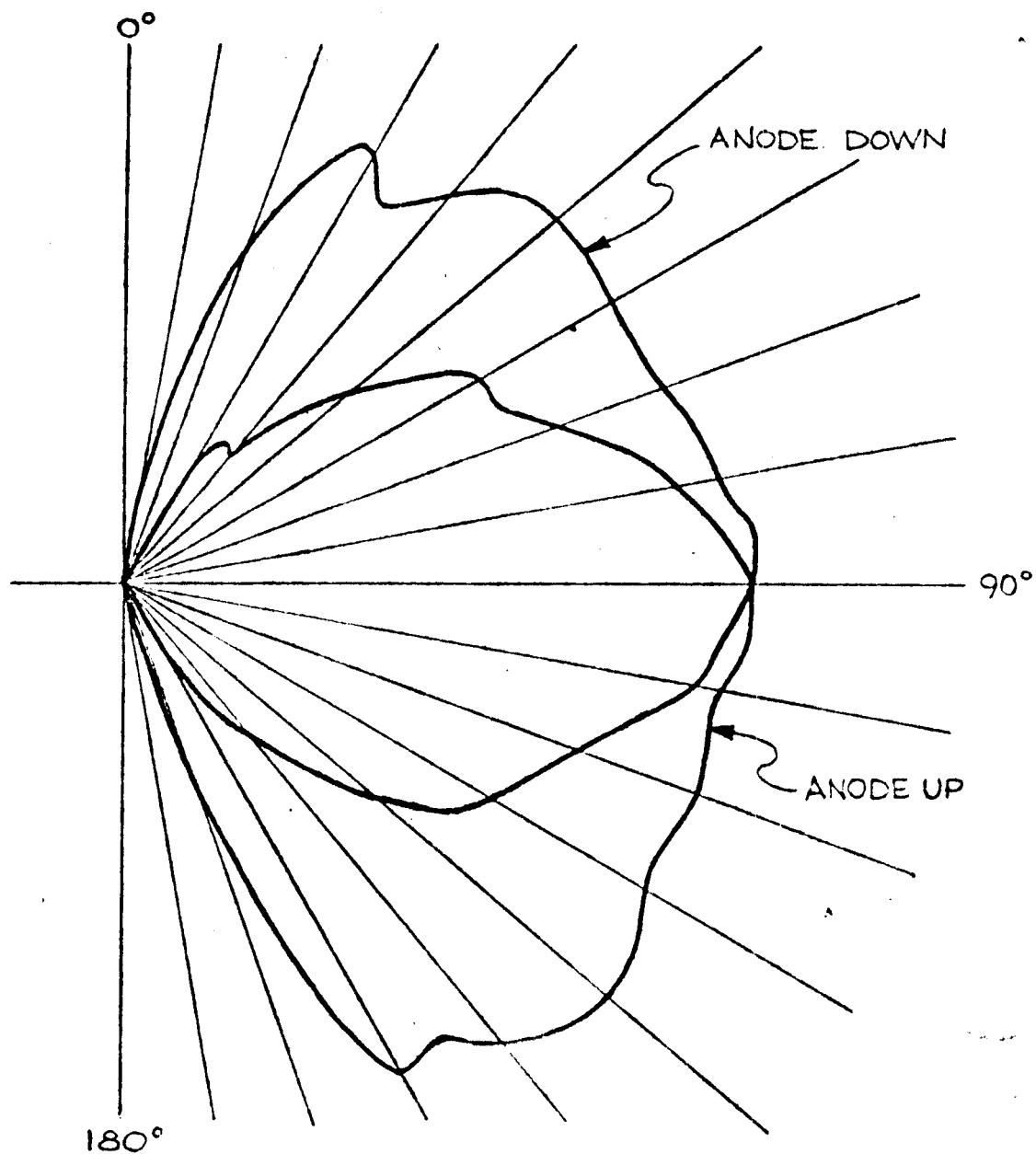


FIGURE 17

RELATIVE
POLAR DISTRIBUTION
FOR WESTINGHOUSE LAMP # R-10
WITH SPHERICAL ANODE
OPERATED WITH ANODE DOWN

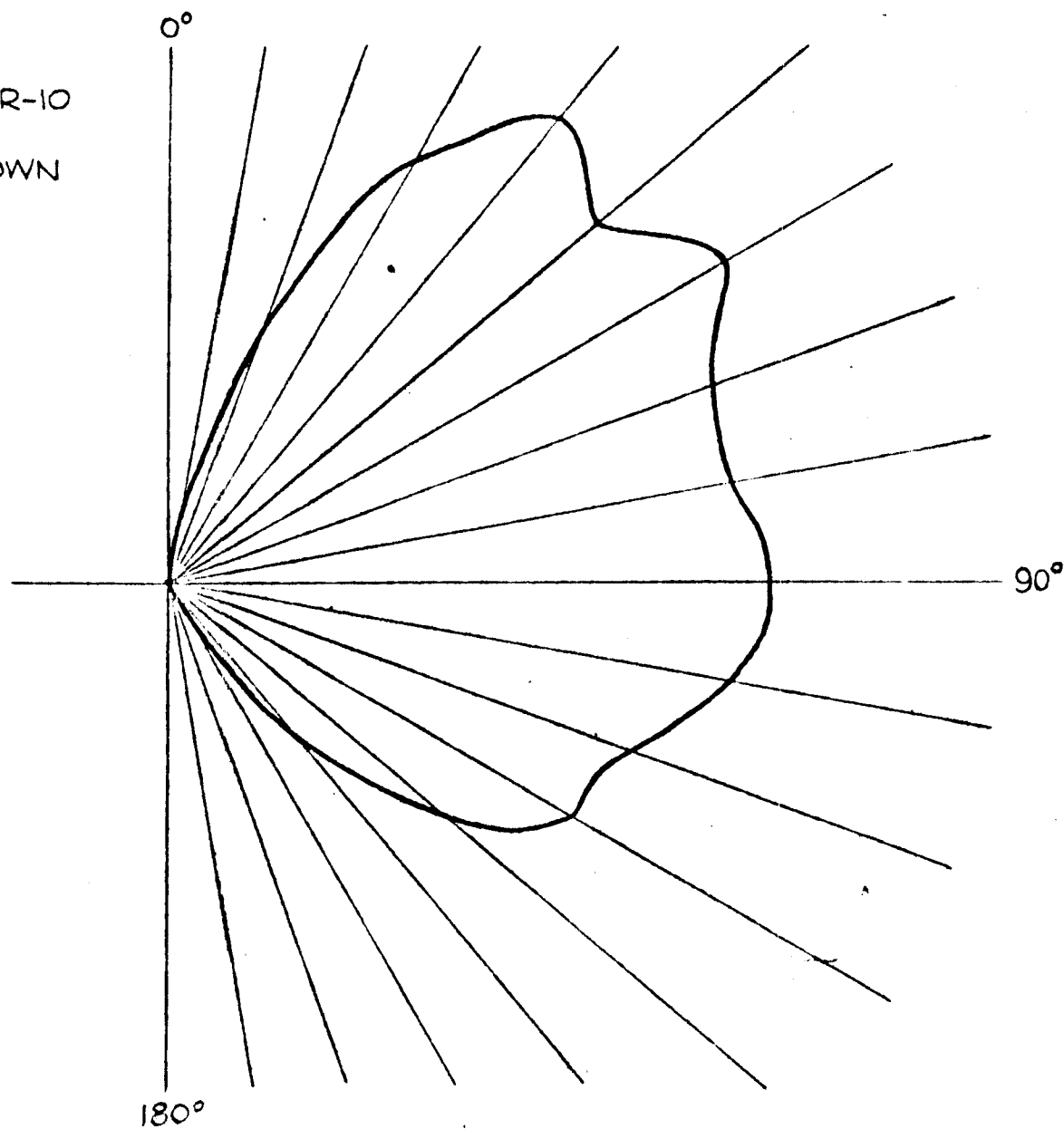


FIGURE 18

25

RELATIVE
POLAR DISTRIBUTION
FOR WESTINGHOUSE LAMP R-II
WITH SPHERICAL ANODE
OPERATED WITH ANODE DOWN

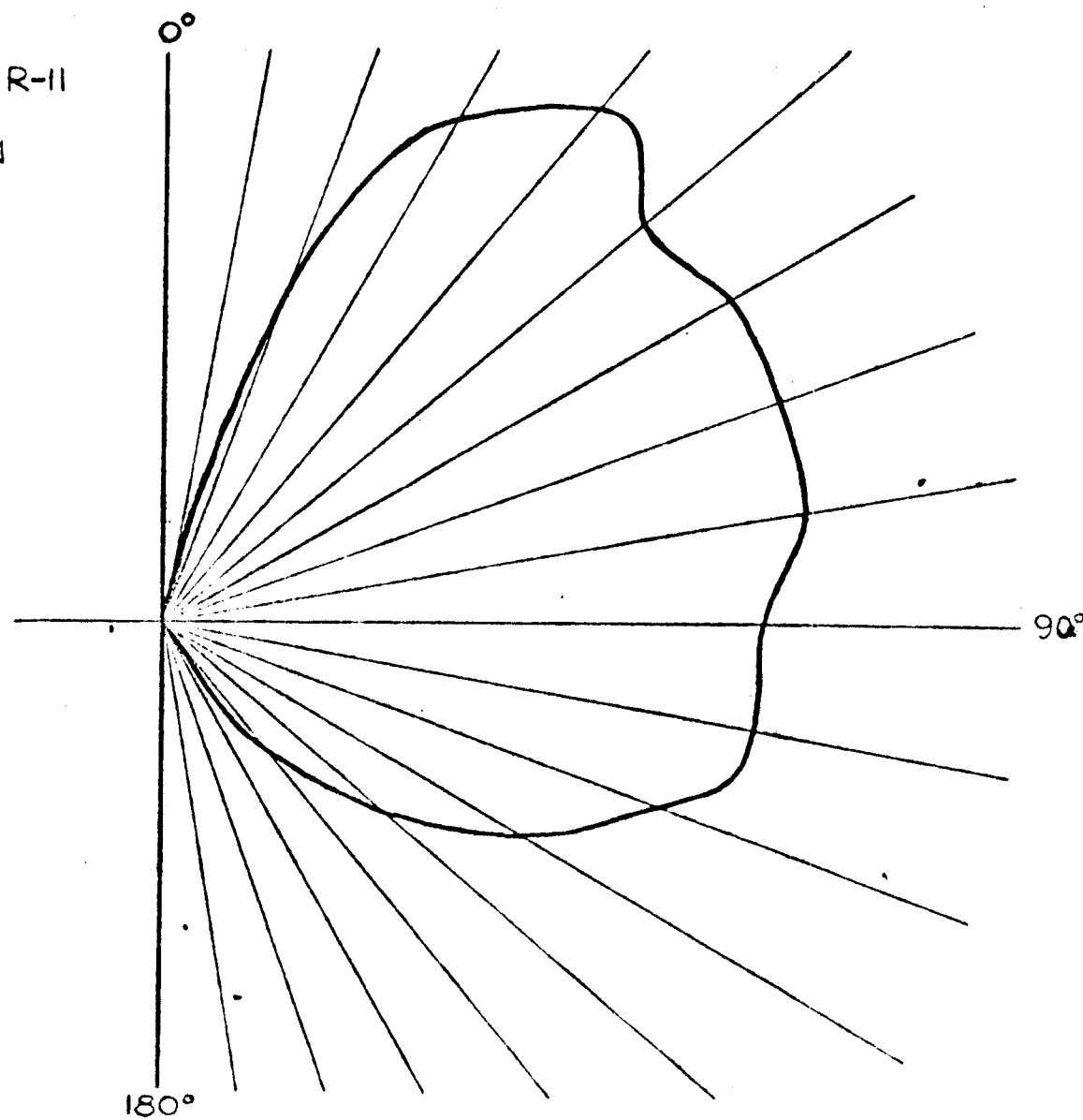


FIGURE 19

24

RELATIVE
POLAR DISTRIBUTION
FOR WESTINGHOUSE LAMP R-II
WITH SPHERICAL ANODE
OPERATED WITH ANODE DOWN

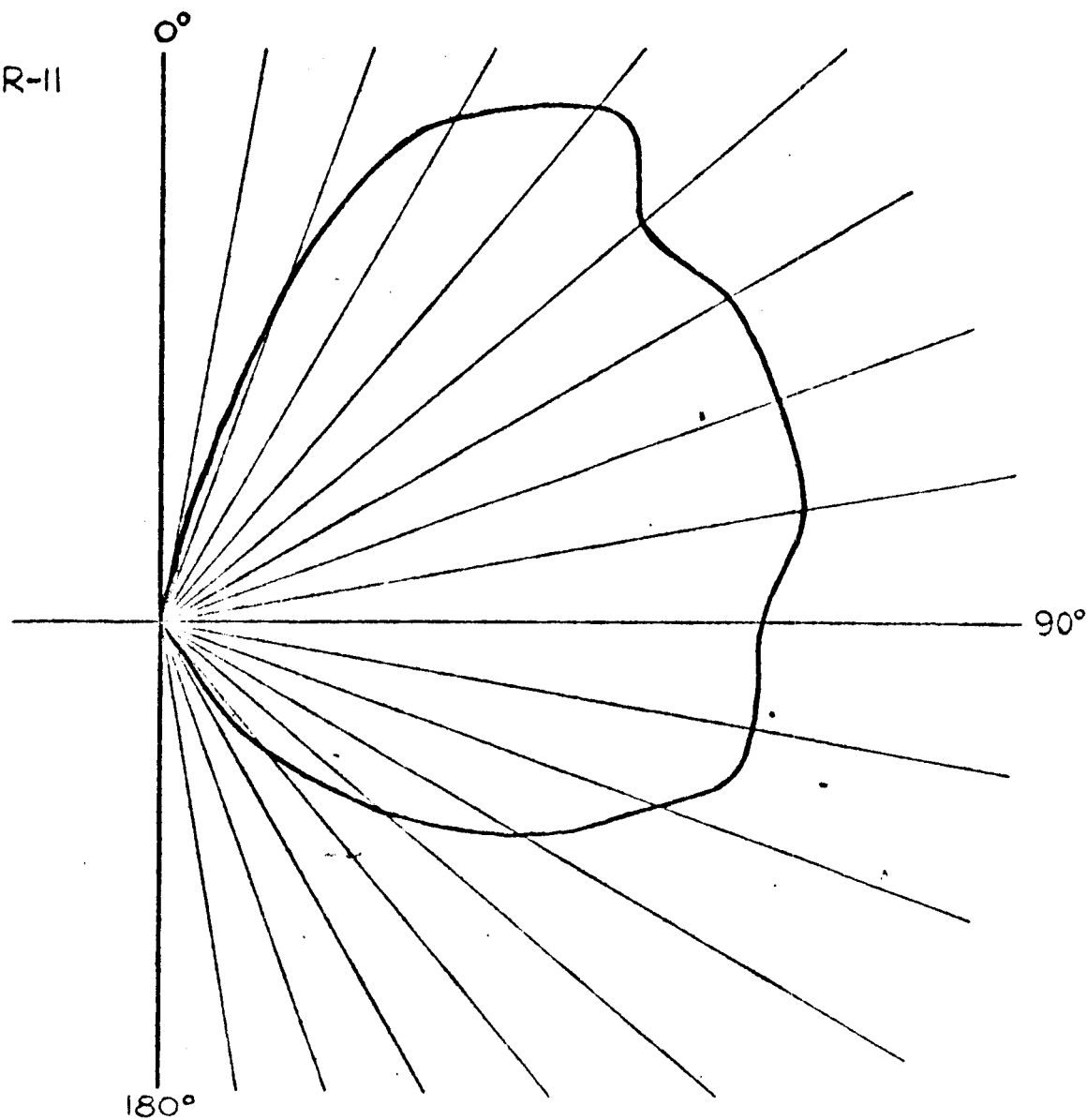


FIGURE 20

RELATIVE
POLAR DISTRIBUTION
FOR 2 WESTINGHOUSE LAMPS
WITH CONICAL ANODES
R-7 - NEW LAMP
R-3 - 128 HOURS OF LIFE
OPERATED WITH ANODE UP

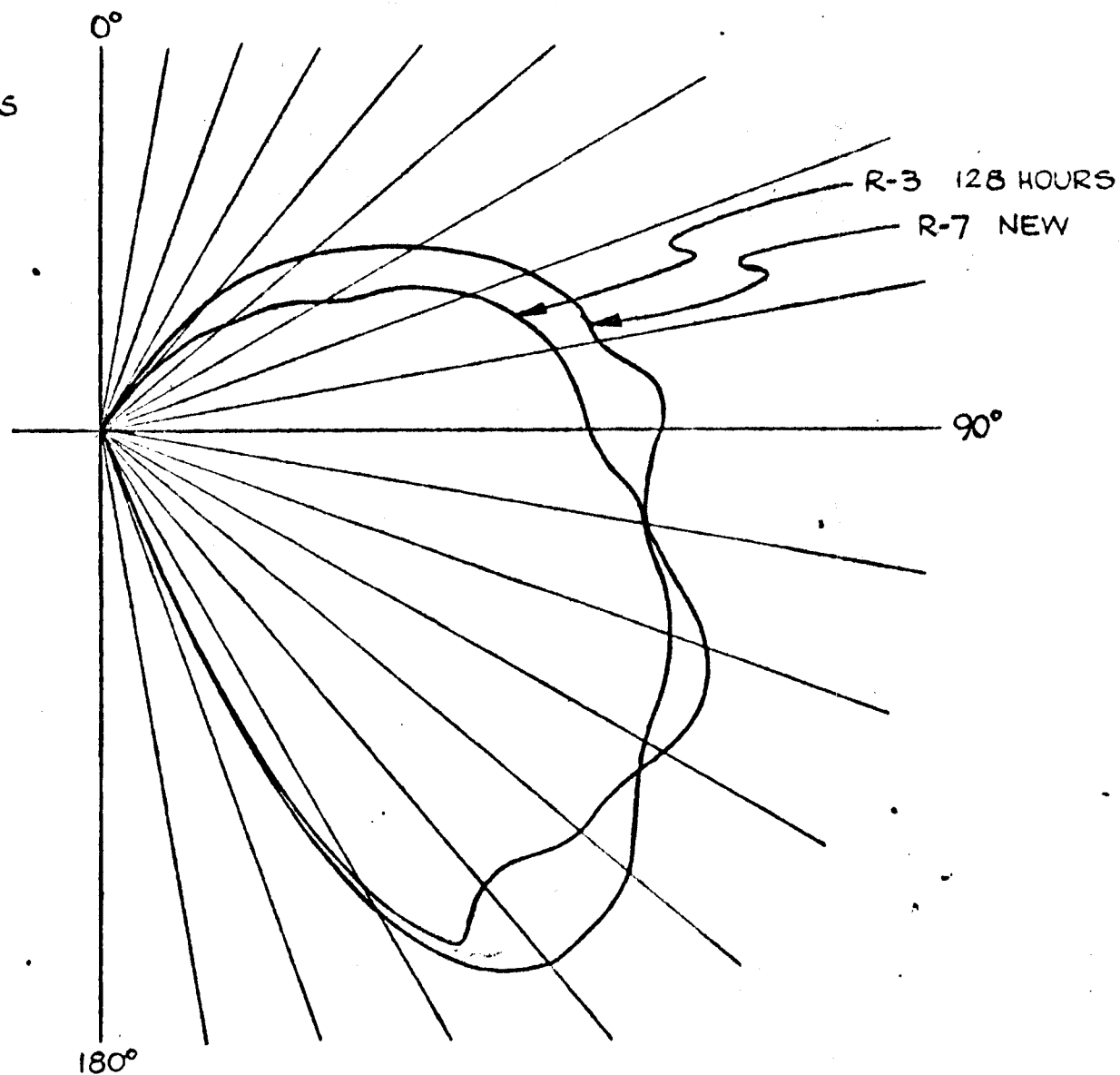
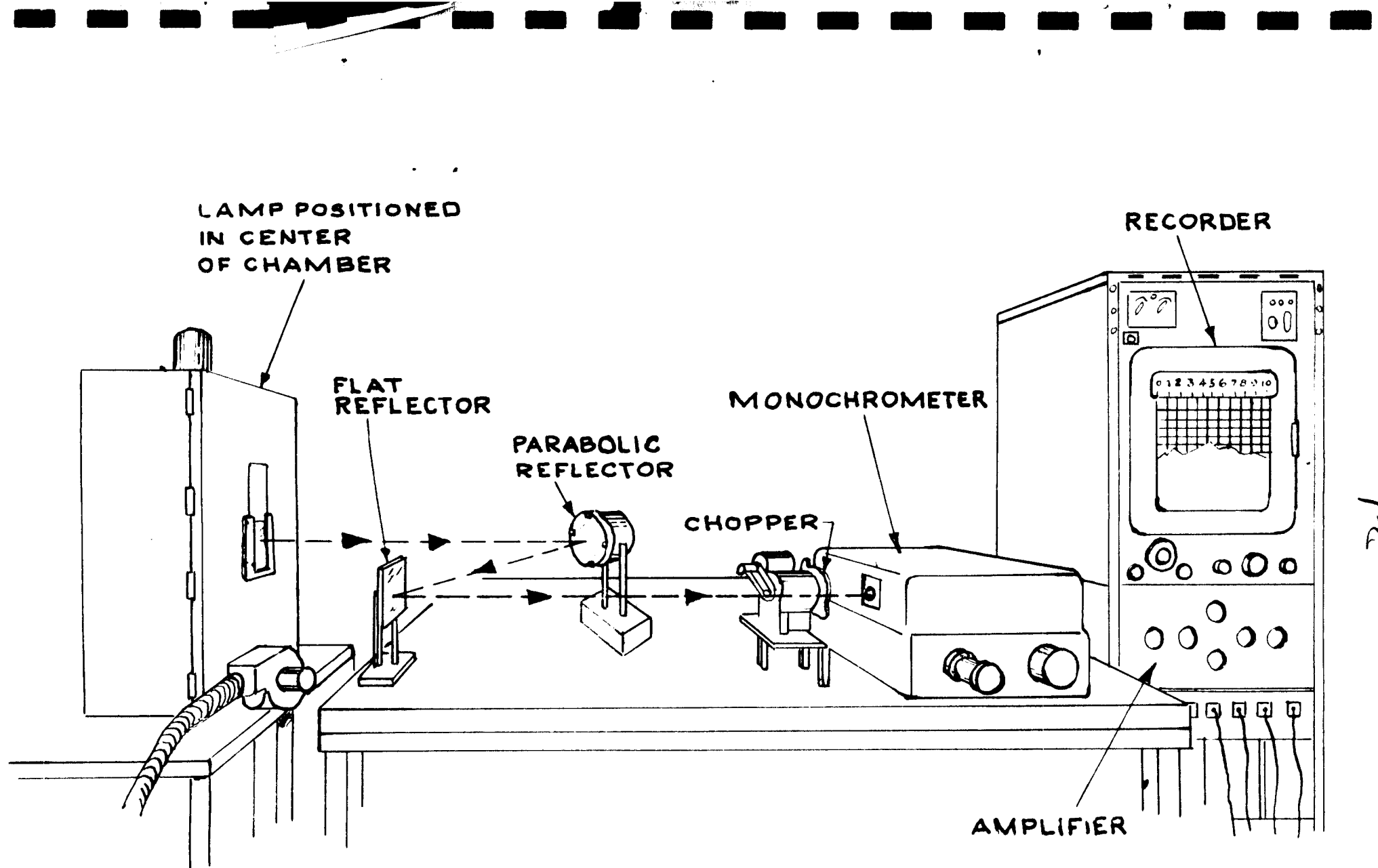


FIGURE 21

22



SET-UP FOR TAKING SPECTRO MEASUREMENTS
FIGURE 22

21

LOG (RELATIVE INTENSITY)

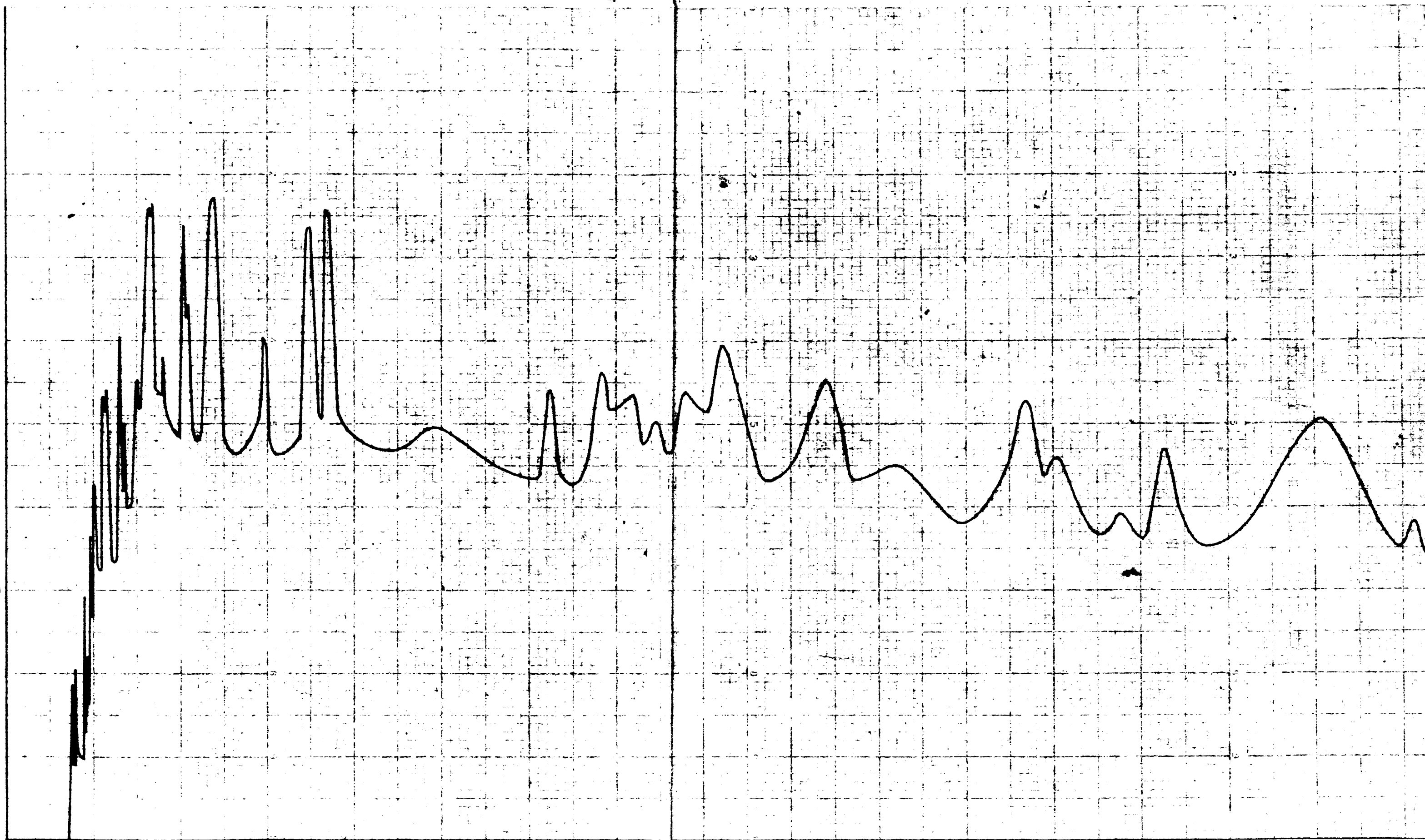
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0

200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800

MILLIMICRONS FIG.23

17

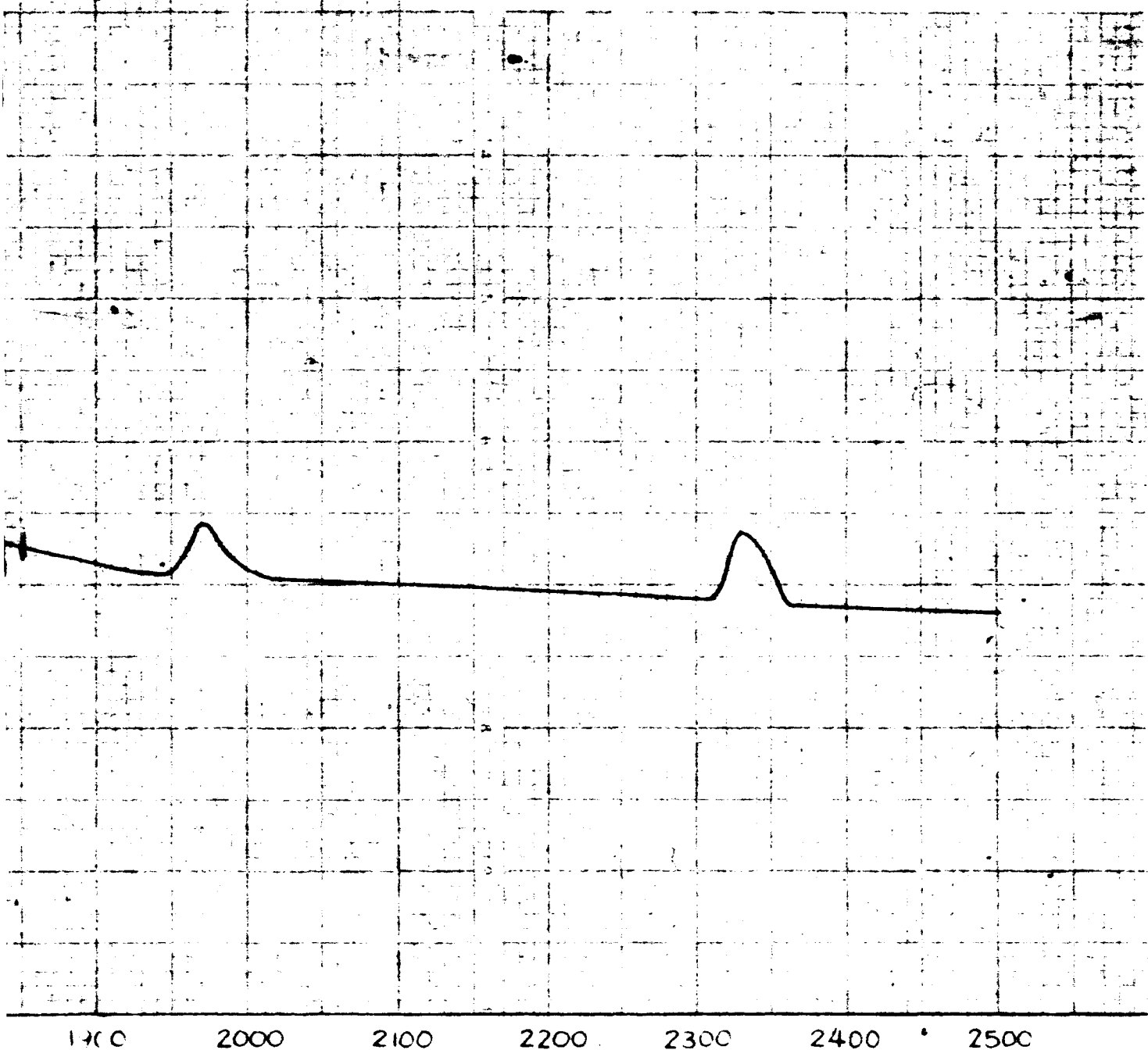
17A



RELATIVE SPECTRAL DISTRIBUTION

WESTINGHOUSE SAHX 2500B # 12R
AMPERES - 46.5
VOLTS - 34
WATTS - 1580

SLIT WIDTH - 0.2 mm
LAMP OPERATED ANODE UP



1700

2000

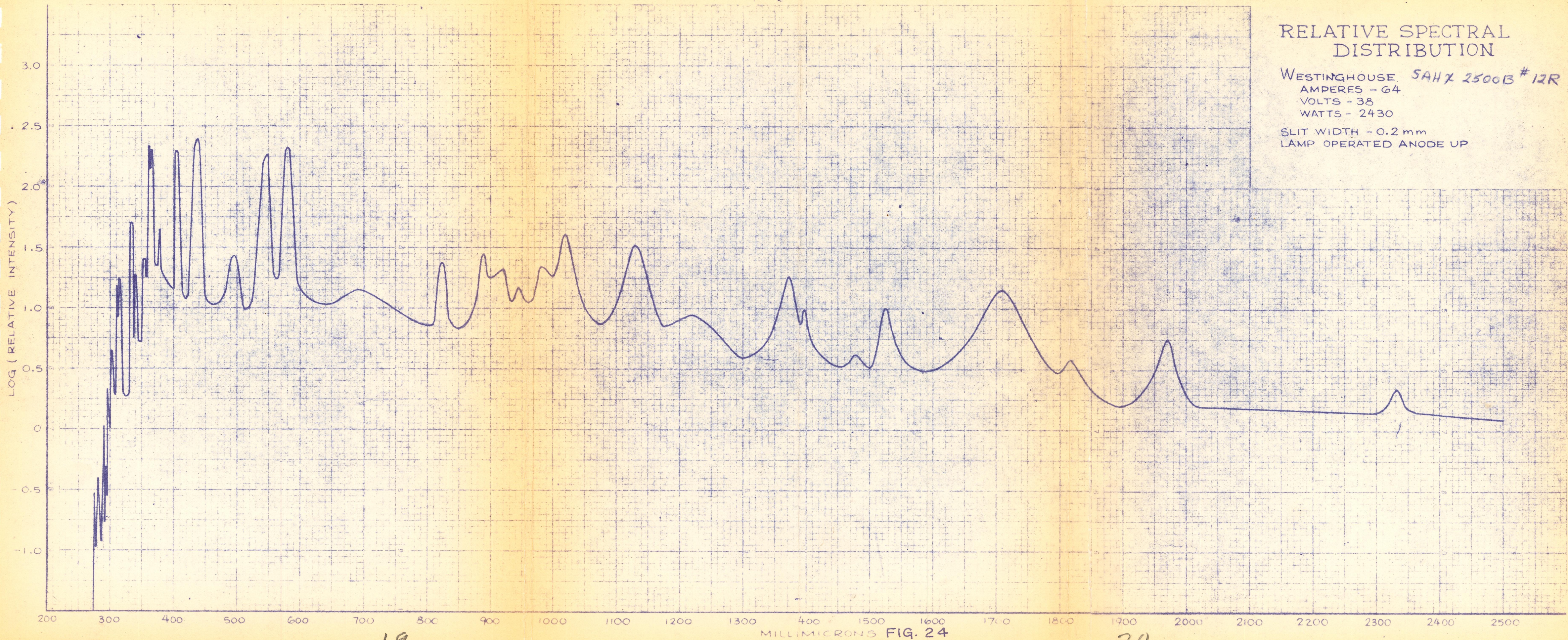
2100

2200

2300

2400

2500



RELATIVE SPECTRAL DISTRIBUTION

WESTINGHOUSE SAHX 2500B (CU) #12K
HOURS OF OPERATION - 1
SLIT WIDTH 0.1 mm

LOG (RELATIVE INTENSITY)

3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0

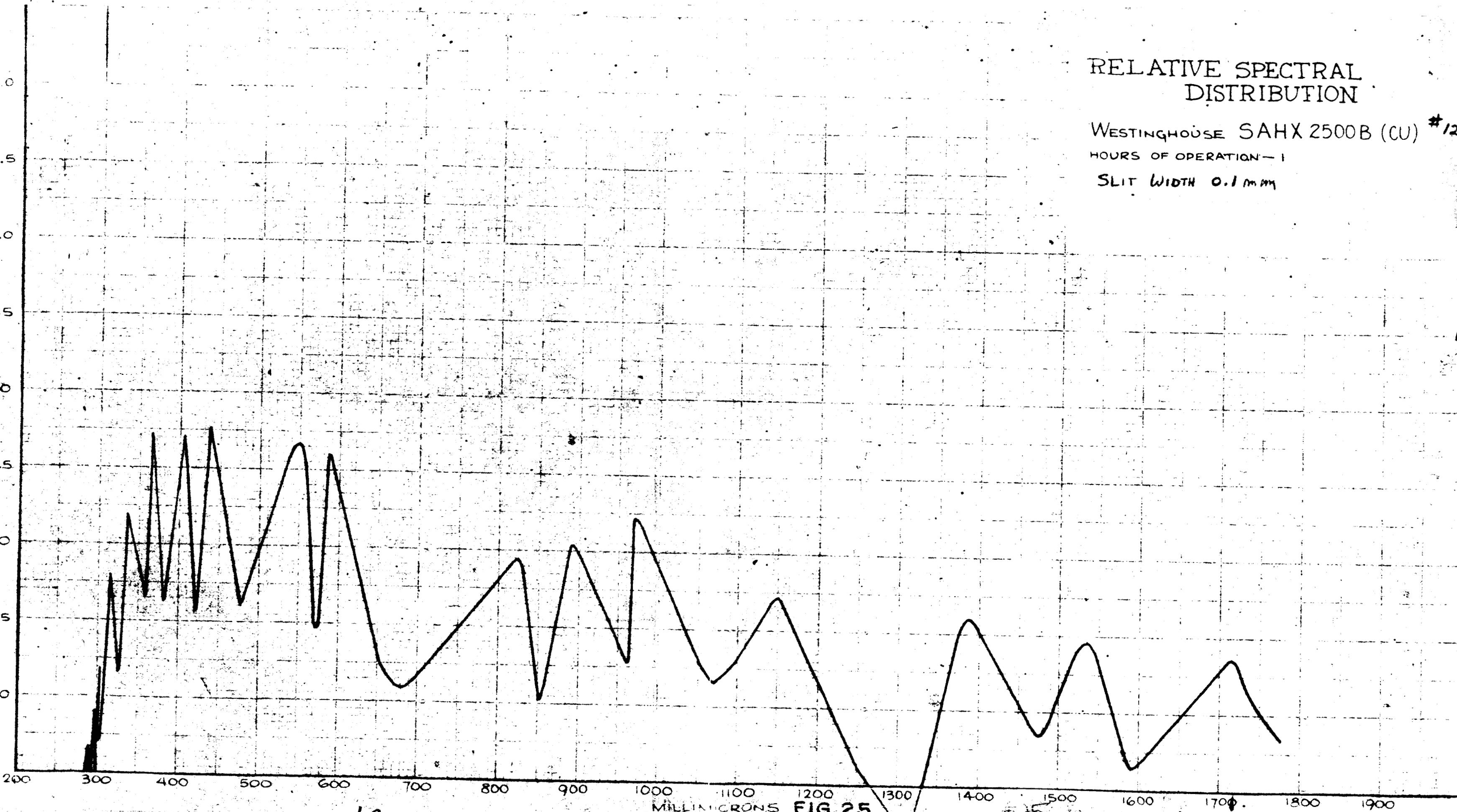
200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900

MILLIMICRONS FIG. 25

19

19A

20

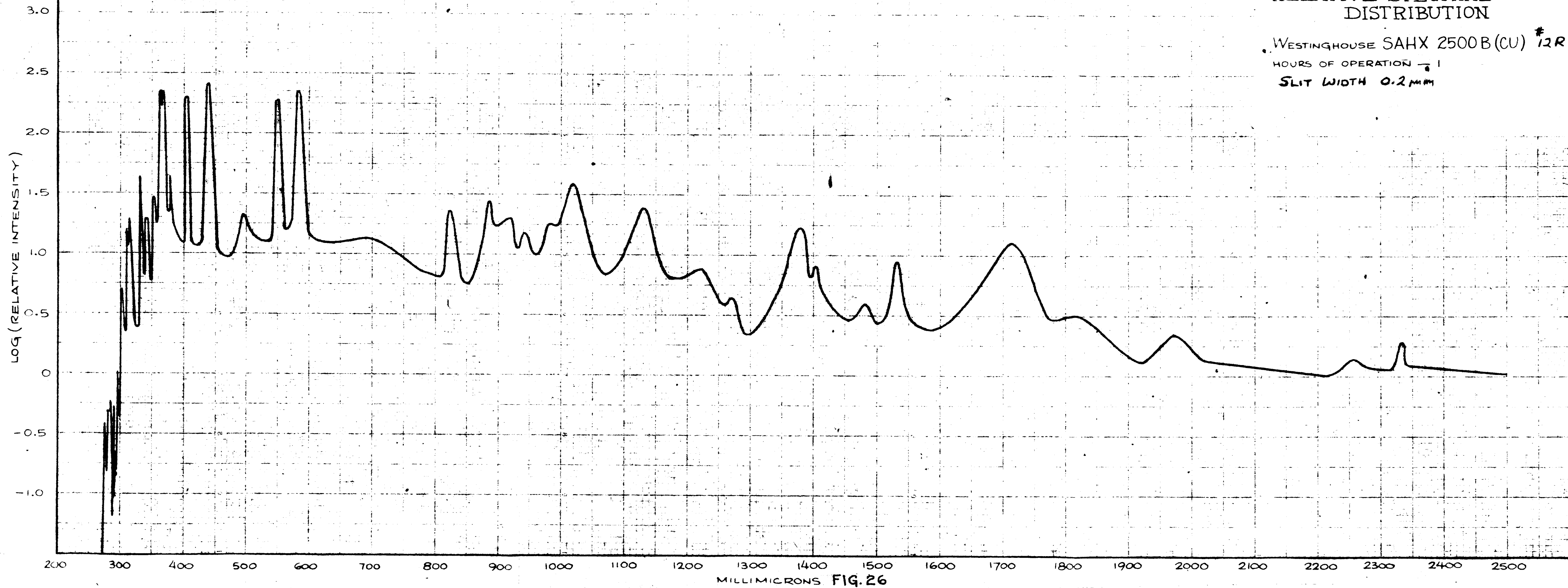


RELATIVE SPECTRAL
DISTRIBUTION

WESTINGHOUSE SAHX 2500B(CU) #12R

HOURS OF OPERATION 1

SLIT WIDTH 0.2 mm



21

21A

22

22

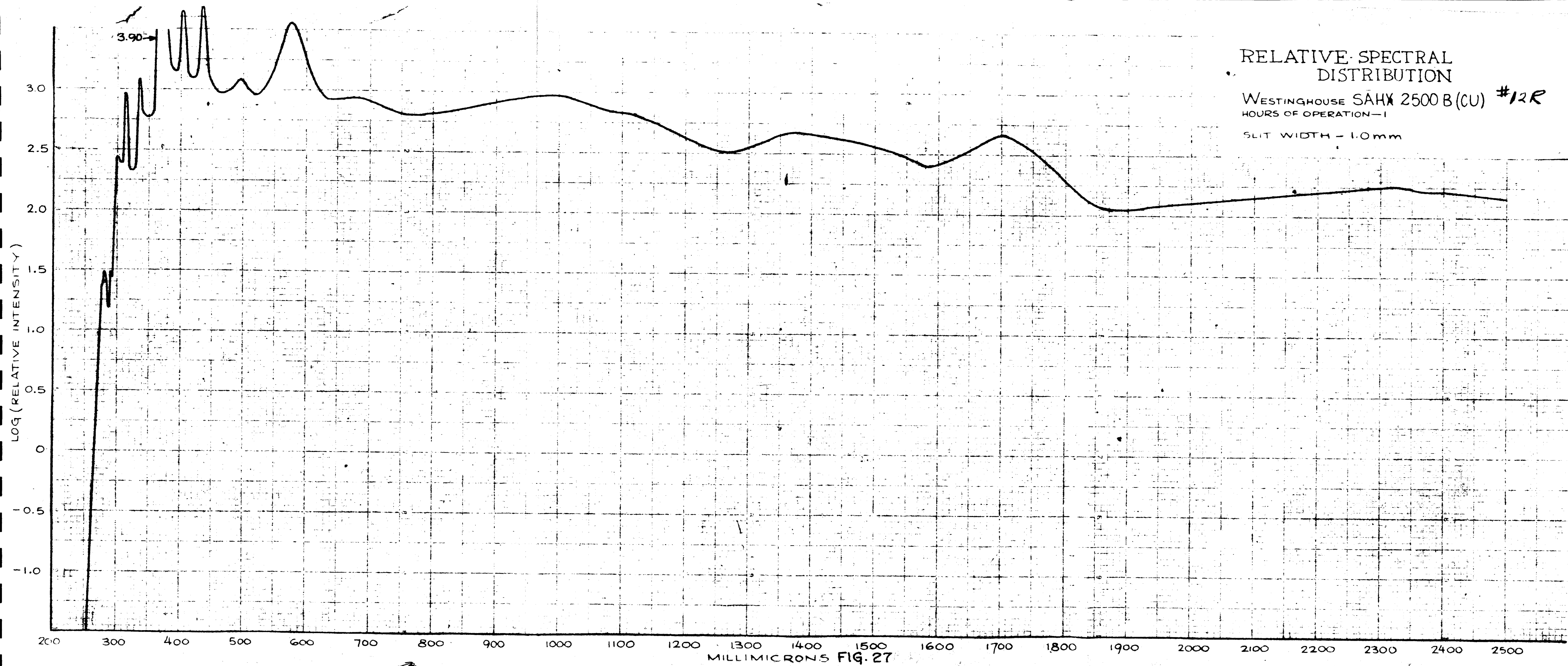


FIG. 27

23

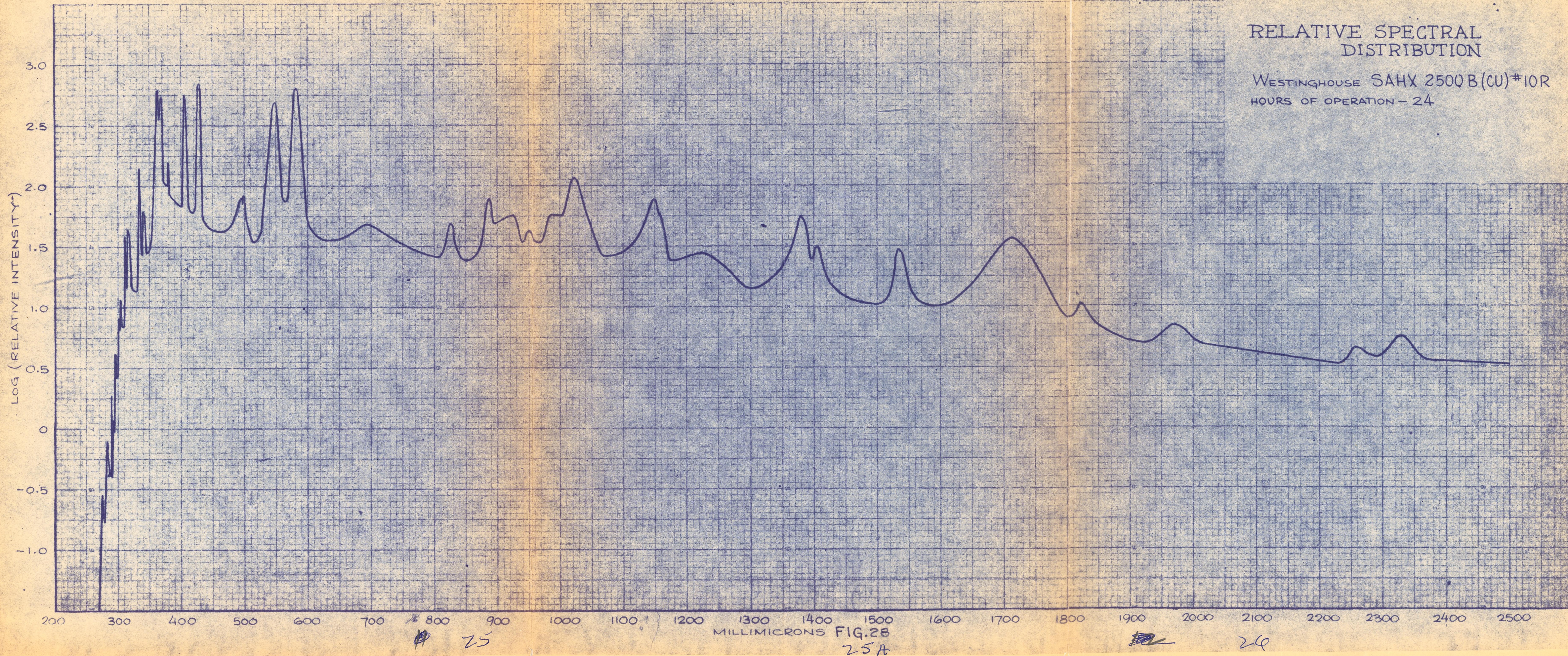
23A

24

24

RELATIVE SPECTRAL
DISTRIBUTION

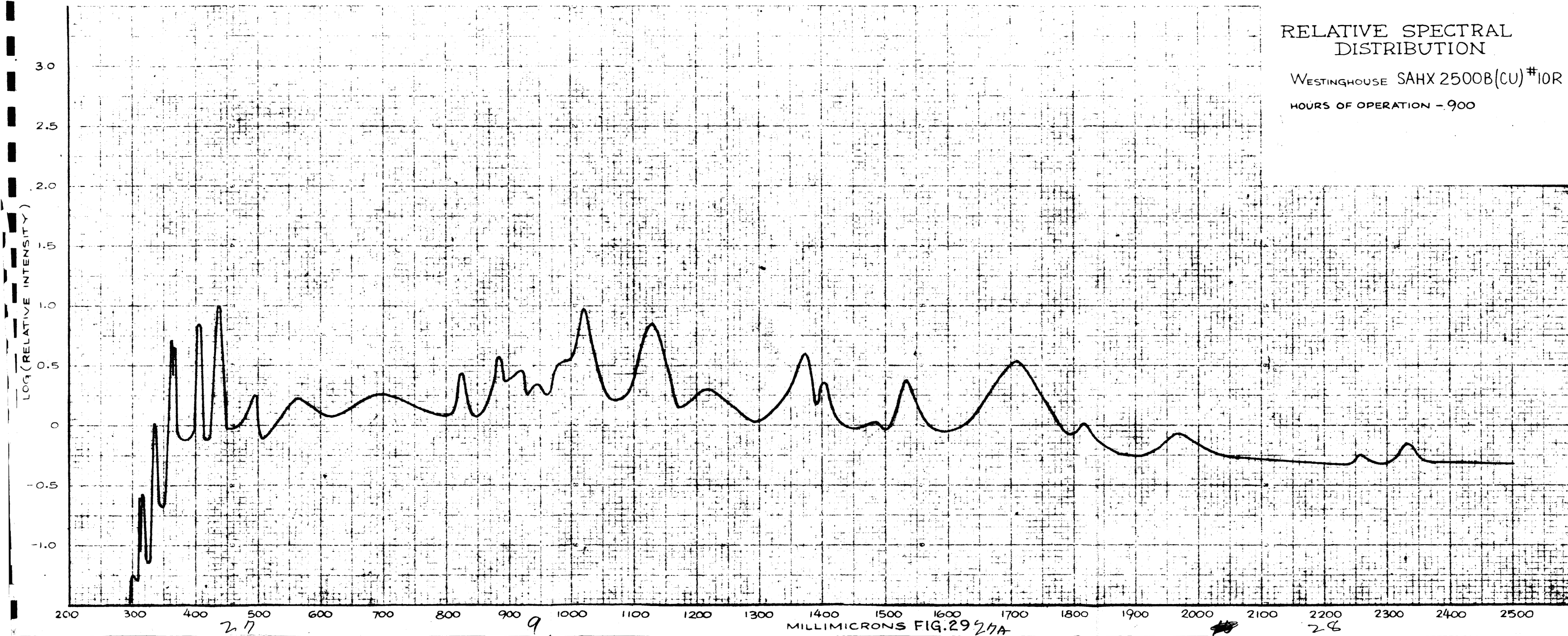
WESTINGHOUSE SAHX 2500 B(CU) #10R
HOURS OF OPERATION - 24



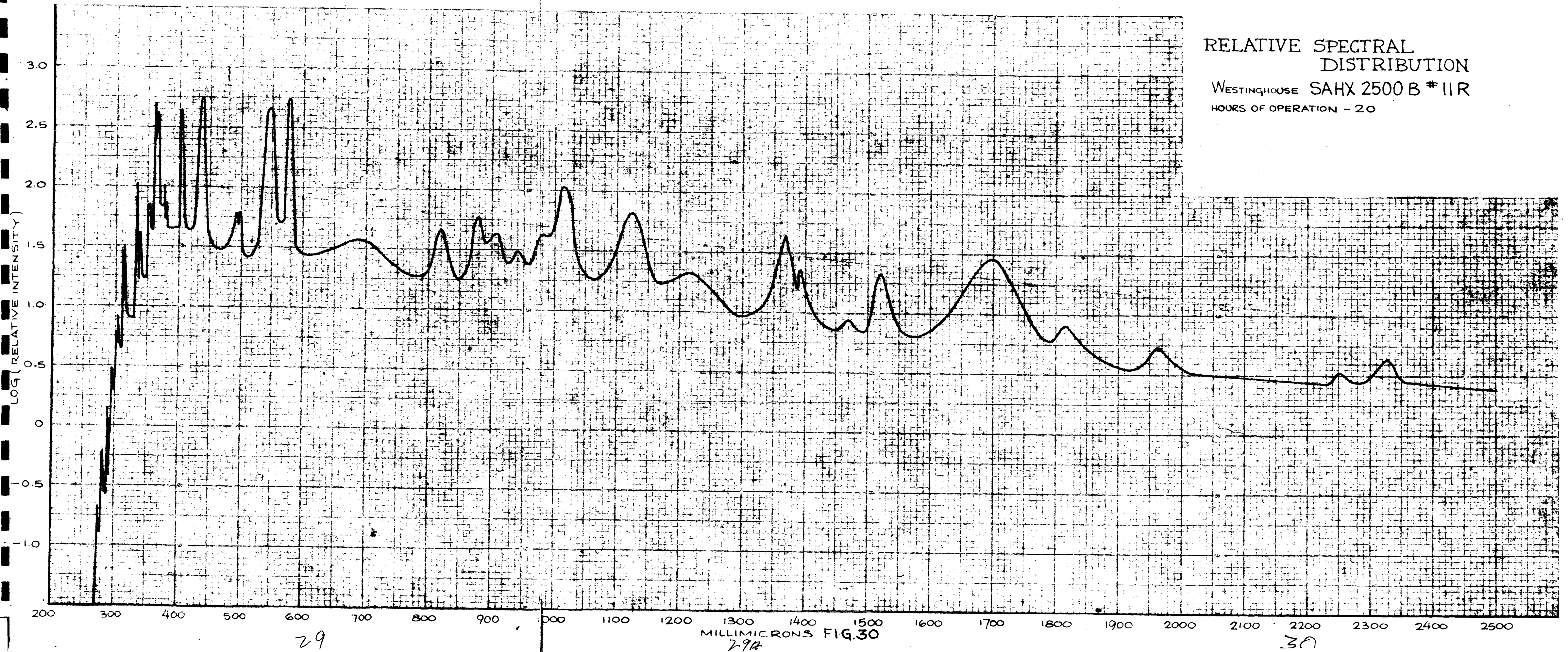
RELATIVE SPECTRAL
DISTRIBUTION

WESTINGHOUSE SAHX 2500B(CU) #10R

HOURS OF OPERATION - 900



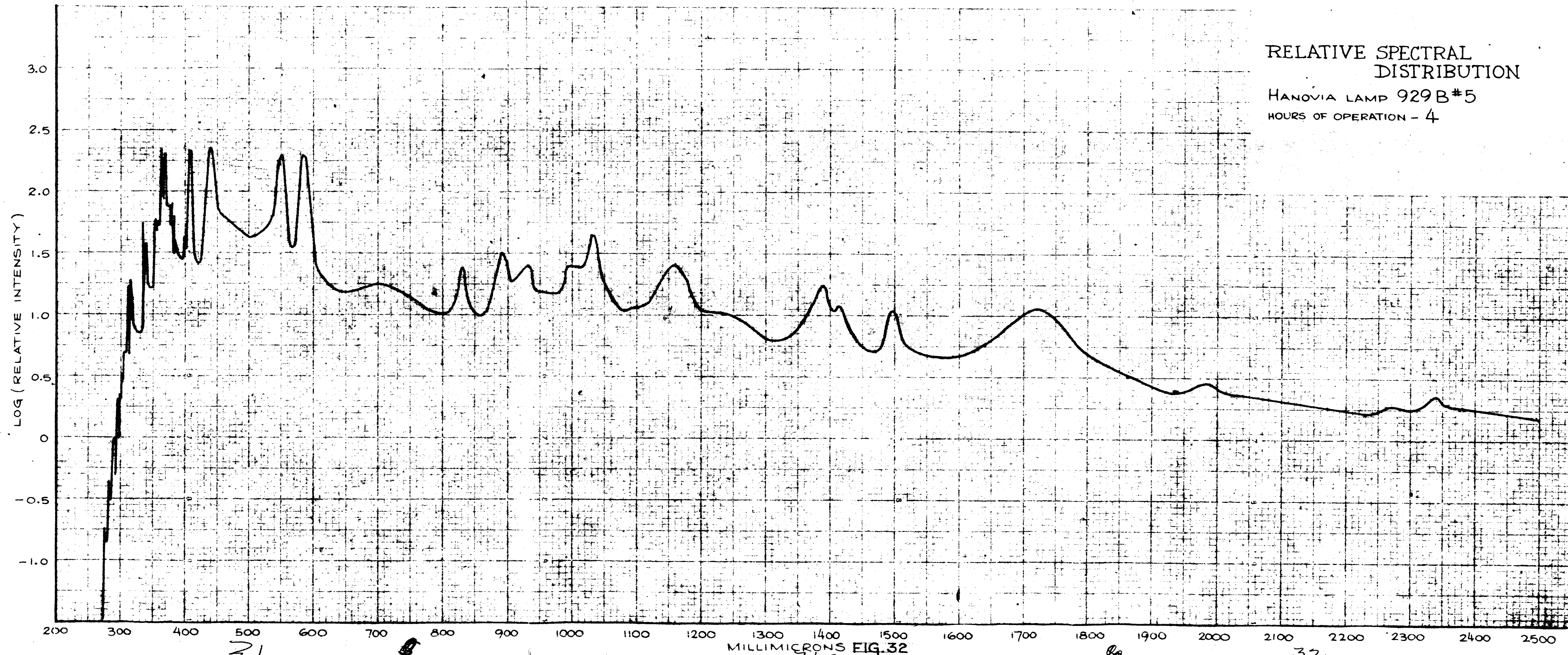
RELATIVE SPECTRAL
DISTRIBUTION
WESTINGHOUSE SAHX 2500 B #11R
HOURS OF OPERATION - 20



RELATIVE SPECTRAL
DISTRIBUTION

HANOVIA LAMP 929B#5

HOURS OF OPERATION - 4



RELATIVE SPECTRAL DISTRIBUTION

HANOVIA LAMP 929B #5

HOURS OF OPERATION - 783

LOG (RELATIVE INTENSITY)

3.0

2.5

2.0

1.5

1.0

0.5

0

-0.5

-1.0

• 2000

400

500

600

700

800

900

1000

1100

1200

1300

1400

1500

1600

1700

1800

1900

2000

2100

2200

2300

2400

2500

MILLIMICRONS FIG. 33

36

RELATIVE SPECTRAL
DISTRIBUTION

HANOVIA LAMP 929B#5

HOURS OF OPERATION - 4

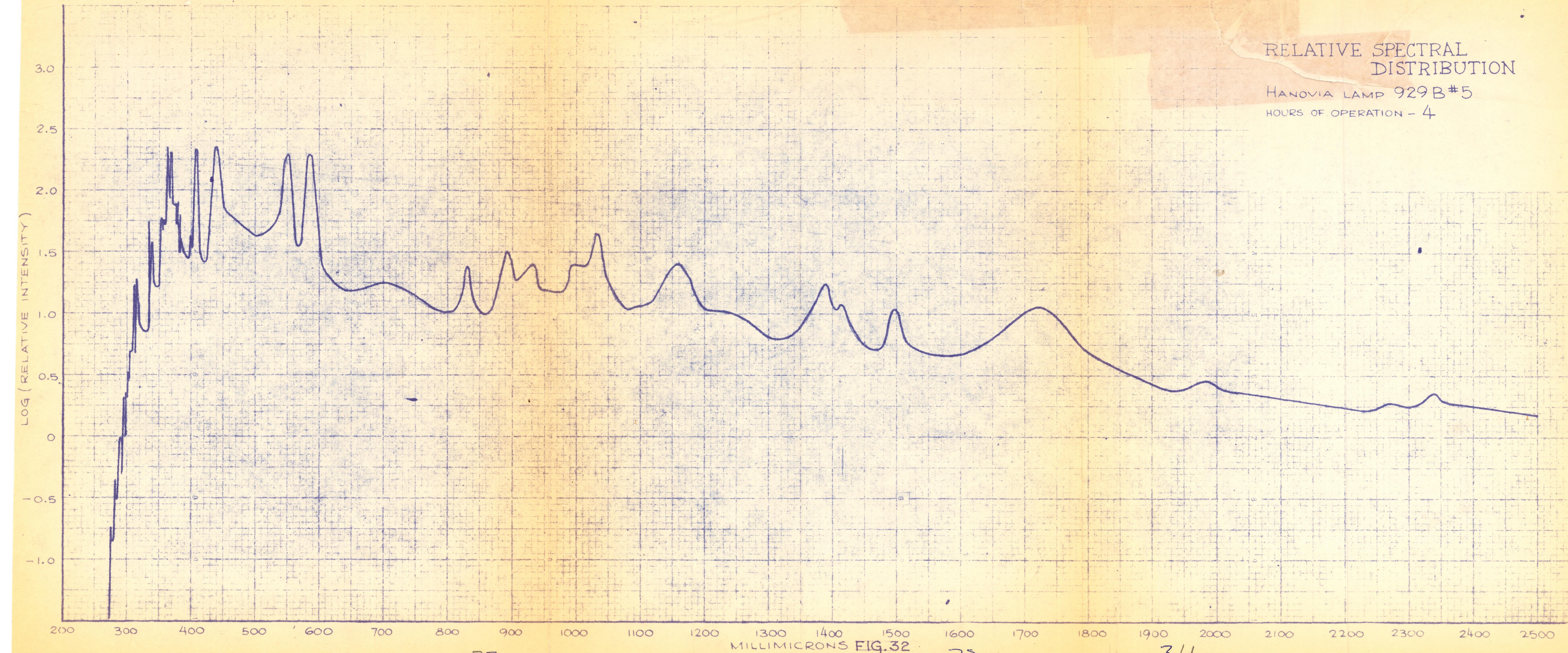


FIG. 32

33

33A

34

RELATIVE SPECTRAL DISTRIBUTION

HANOVIA LAMP 929B #5

HOURS OF OPERATION - 783

LOG (RELATIVE INTENSITY)

3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0

200 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500

MILLIMICRONS FIG. 33

35

35A

36